ZooKeys 1169: 95–162 (2023)
DOI: 10.3897/zookeys.1169.97812

Review Article

Terrestrial crustaceans (Arthropoda, Crustacea): taxonomic diversity, terrestrial adaptations, and ecological functions

Ivan N. Marin[1], Alexei V. Tiunov[1]

1 *A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow 119071, Russia*
Corresponding author: Ivan N. Marin (coralliodecapoda@mail.ru)

Abstract

Terrestrial crustaceans are represented by approximately 4,900 species from six main lineages. The diversity of terrestrial taxa ranges from a few genera in Cladocera and Ostracoda to about a third of the known species in Isopoda. Crustaceans are among the smallest as well as the largest terrestrial arthropods. Tiny microcrustaceans (Branchiopoda, Ostracoda, Copepoda) are always associated with water films, while adult stages of macrocrustaceans (Isopoda, Amphipoda, Decapoda) spend most of their lives in terrestrial habitats, being independent of liquid water. Various adaptations in morphology, physiology, reproduction, and behavior allow them to thrive in virtually all geographic areas, including extremely arid habitats. The most derived terrestrial crustaceans have acquired highly developed visual and olfactory systems. The density of soil copepods is sometimes comparable to that of mites and springtails, while the total biomass of decapods on tropical islands can exceed that of mammals in tropical rainforests. During migrations, land crabs create record-breaking aggregations and biomass flows for terrestrial invertebrates. The ecological role of terrestrial microcrustaceans remains poorly studied, while omnivorous macrocrustaceans are important litter transformers and soil bioturbators, occasionally occupying the position of the top predators. Notably, crustaceans are the only group among terrestrial saprotrophic animals widely used by humans as food. Despite the great diversity and ecological impact, terrestrial crustaceans, except for woodlice, are often neglected by terrestrial ecologists. This review aims to narrow this gap discussing the diversity, abundance, adaptations to terrestrial lifestyle, trophic relationships and ecological functions, as well as the main methods used for sampling terrestrial crustaceans.

Key words: Crustacea, ecosystem engineers, food webs, morphological adaptations, soil animals, terrestrialization, trophic ecology

OPEN ACCESS

Academic editor: Stefano Taiti
Received: 21 November 2022
Accepted: 29 May 2023
Published: 13 July 2023

ZooBank: https://zoobank.org/9DC53094-81FC-4609-AB04-EFE9DE38A578

Citation: Marin IN, Tiunov AV (2023) Terrestrial crustaceans (Arthropoda, Crustacea): taxonomic diversity, terrestrial adaptations, and ecological functions. ZooKeys 1169: 95–162. https://doi.org/10.3897/zookeys.1169.97812

Copyright: © Ivan N. Marin & Alexei V. Tiunov. This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

The subphylum Crustacea represents one of the largest and morphologically diverse taxa within the phylum Arthropoda (clade Mandibulata) with more than 70,000 known species, inhabiting all major ecosystems on Earth, except the airspace (Schram 1986). Some recent molecular studies show that the subphylum Crustacea is paraphyletic and includes all animals in the Pancrustacea clade, except for Hexapoda (Rota-Stabelli et al. 2010). However, some crustaceans of the Vericrustacea group (e.g., Anostraca, Copepoda, Malacostraca, and others) are closely related to insects (Insecta) than to other crustaceans

from the Oligostraca clade (e.g., Ostracoda) (Koenemann et al. 2010; Regier et al. 2010). By other analysis, the clade Pancrustacea includes Hexapoda, being the most diverse group of animals on Earth (Bernot et al. 2022).

The main lineages of Crustacea appeared in the Cambrian time, being presumably marine aquatic animals (Chen et al. 2001; Schwentner et al. 2017). Since then, various lineages of crustaceans have tried to conquer the land, and many have succeeded. The first terrestrial crustaceans may have colonized the soil through marine basins during the Carboniferous period, ~ 360–300 Mya (Golonka and Ford 2000), and then filled ecological niches in moist and shaded soils in forests on coastal flood plains (Williams et al. 2006; Bennett 2008; Broly et al. 2013a). Their land colonization process occurred later than in the insects' ancestors, which probably left the sea in the Lower Devonian, ~ 405 Mya (Grimaldi 2010; Watson-Zink 2021). The recent phylogenetic conclusions on Talitroidea have shown that their ancestors appeared no later than the Jurassic period, with the radiation of the ancestor taxa well established by the beginning of the Cretaceous period, ~ 140–138 Mya, being semi-terrestrial amphipods living close to the sea in swamps and mangrove forests (Myers and Lowry 2020). The first attested occurrences of Oniscidea (woodlice), the only modern group of Crustacea almost entirely composed of terrestrial forms, are recorded from the Early Cretaceous (100.5–66 Mya), while the paleobiogeographic context of fossil specimens and current biological considerations support a pre-Pangaea origin of the Oniscidea, in the Late Paleozoic, 350–250 Mya, most likely during the Carboniferous period (Carefoot and Taylor 1995; Tabacaru and Danielopol 1996; Broly et al. 2013a). Decapod crustaceans colonized the terrestrial habitats significantly later. For example, true crabs (Brachyura) independently colonized terrestrial habitats several times and separated from related marine/estuarine or freshwater relatives during the Late Cretaceous Period (100.5–66 Mya) (Watson-Zink 2021; Wolfe et al. 2022). Land-dwelling lifestyle has become the main factor of their further diversification, and numerous semi-terrestrial and terrestrial lineages radiated in the Early Eocene, which possibly coincided with global warming during the Paleocene-Eocene Thermal Maximum (~ 55 Mya) (Tsang et al. 2022). Colonization of terrestrial habitats has probably occurred relatively recently in Ostracoda and Branchiopoda, with marine eurytopic species colonized terrestrial niches from brackish and fresh waters in coastal floodplains (Williams et al. 2006; Bennett 2008).

Present-day terrestrial crustaceans thrive in very diverse habitats and may even be the predominant life form in some land ecosystems (Hansson et al. 2011). They were among the first invertebrates discovered and described by scientists. The land crab *Cancer ruricola* (= *Gecarcinus ruricola*) and woodlouse *Oniscus asellus* were described by Linnaeus (1758) in "Systema Naturae". European sand- and landhoppers, for example, *Talitrus grillus* (= *Speziorchestia grillus*), were also described at the dawn of the diversity studies (Bosc 1802; Latreille 1802; Montagu 1808). The first terrestrial ostracod *Mesocypris pubescens* and harpacticoids from genera *Epactophanes* and *Parastenocaris* were discovered in the early 20th century from mosses and epiphytes of the cloud forests of Africa (Daday 1910) and Indonesia (Menzel 1916, 1921, 1923, 1926), respectively, while Chappuis (1928a, 1982b, 1930) described several tiny harpacticoids from mosses of the Himalayas' foothills. The first truly terrestrial brachiopodans (= cladocerans), *Bryospilus repens* and *Bryospilus bifidus* (Chydoridae), were

discovered in 1980 in epiphytic mosses and the litter of cloud and rain forests of Puerto Rico, Venezuela, and New Zealand (Frey 1980). Nevertheless, crustaceans, except for woodlice, are not usually regarded as a group characteristic of terrestrial habitats. Despite their abundance and obvious importance in many habitats of tropical and ex-tropical terrestrial ecosystems, their ecological role and impact remain underestimated and undeservedly overlooked by "terrestrial" soil zoologists and ecologists (Fiers and Ghenne 2000).

In the review, we provide an overview of published data on the diversity, abundance, and ecological role of crustaceans living in terrestrial environments, excluding subterranean habitats, phytothelmata and other small water reservoirs, peat bogs, and other habitats providing a constant aquatic environment. We consider terrestrial those crustaceans whose adult stages spend most of their lives in terrestrial habitats more or less isolated from water sources. We aimed to show that crustaceans are among the functionally important components of terrestrial biodiversity, although their impact on ecosystem processes often remains underestimated. This review includes three main parts: 1) diversity and abundance in terrestrial habitats; 2) most important morphological, physiological, and behavioral adaptations; 3) trophic connections and functional role in ecosystems. In addition, we provide a brief description of the main methods that could be useful for sampling terrestrial crustaceans.

Diversity and abundance in terrestrial habitats

Habitats and distribution

Even well-drained terrestrial habitats contain a large amount of water, mainly in the form of surface water films and capillary soil moisture (Ghilarov 1956; Robinson et al. 2008). Water-filled pores and microfilms are also abundant in moist organic epigean substrates such as leaf litter or moss cushions. The total volume of this "cryptic water" is almost equal to the combined volume of freshwater lakes and rivers (Hutchinson 1957; Bittelli 2011).

Dependence on cryptic water underlies a traditional division of terrestrial crustaceans into two ecological (not phylogenetic) groups: microcrustaceans and macrocrustaceans (Table 1) (Hurley 1968; Little 1983).

Table 1. Comparative ecological characteristics of micro- and macrocrustaceans.

	Microcrustacea	Macrocrustacea
Taxa	Branchiopoda, Ostracoda, Copepoda	Malacostraca (Amphipoda, Isopoda, Decapoda)
Size	Total body length < 1 mm; body mass < 1 mg	Total body length from 2–3 mm to 120 mm; body mass up to 4 kg
Diversity	~ 220 known terrestrial or semi-terrestrial species	~ 4500 known terrestrial or semi-terrestrial species
Water	Depend on water films during the whole life cycle	Isopoda and Amphipoda mostly independent, Decapoda need liquid water for breeding
Habitats	Moist organic substrates, such as humid leaf litter and moss cushions, wet soils of shorelines and marshes. Branchiopoda and Ostracoda are confined mainly to warm regions	Almost everywhere, including high altitudes, arid deserts, Arctic, and sub-Antarctic tundra; soil, litter, arboreal habitats. Most of Amphipoda and Decapoda are confined to warm regions

Microcrustaceans

Microcrustaceans, represented by Branchiopoda (Cladocera), Ostracoda, and Copepoda, are tiny arthropods with a total body length typically < 1 mm, which are dependent on and associated with surface water films or pore water. These microhabitats are often discrete and restricted in volume and therefore are strongly influenced by wetting, drying, precipitation, drainage, and evaporation. Branchiopods and ostracods are known for permanently wet habitats in tropical and subtropical cloud and rain forests, where they live in thin films and small accumulations of water on the vegetation and forest floor. The most important condition for the survival of these animals is seemingly regular precipitation (Harding 1953, 1955; Schornikov 1969; Frey 1980; Martens et al. 2004; Pinto et al. 2005a). Terrestrial Copepoda (Harpacticoida and Cyclopoida) have a wider distribution range. Harpacticoids have been found in habitats containing only a small amount of capillary water, while the ability to encyst allows them to survive persistent droughts, as well as to spread over long distances with the help of wind or with clumps of moss carried by other animals (Deevey 1941; Glime 2017a). In addition to moist tropical and temperate zones, where they are quite diverse (Dahms and Qian 2004; Martens et al. 2008), they are known for boreal and polar meadow/tundra soils and coastal environments, extending to Arctic and sub-Antarctic (Reid 1986; Flössner 1992; Hansson et al. 1996; Pugh et al. 2002; Marin and Palatov 2023). They have been found also in mountain habitats, for example, harpacticoid *Elaphoidella pseudocornuta* is known from the leaf litter of the wet forests of Nepal at an altitude of 1900–3900 m a.s.l. (Dumont and Maas 1988). Microcrustaceans are probably very widespread in terrestrial biotopes where there is at least a small amount of pore water and extremely low or high temperatures are not reached. Due to their small size, they rarely attract the attention of soil zoologists. Occasionally, the presence of microcrustaceans in soil and other terrestrial habitats is considered an artifact (Fiers 2013) and the actual distribution of microcrustaceans in terrestrial environments is probably underestimated (Fiers and Ghenne 2000).

Macrocrustaceans

Macrocrustaceans, represented by malacostracan orders Amphipoda, Isopoda, and Decapoda, are relatively large arthropods, usually (2–300 mm in the total body length), which are significantly less dependent on water films, pore water, and even soil moisture (Hurley 1968; Little 1983). These crustaceans densely populate coastal marine zone (Bliss and Mantel 1968; Friend and Richardson 1986; Myers and Lowry 2020), tropical and subtropical marine islands (Green 1997; Lindquist et al. 2009), and temperate inland forests, where they occur from the soil of the forest floor to the top tier of the canopy (Richardson 1992; Taylor et al. 1993; Biju Kumar et al. 2017; Ng and Ng 2018; Wongkamhaeng et al. 2018). In favorable terrestrial environments, crustaceans have undergone profound morphological and ecological speciation, and occupy various ecological niches (Schmalfuss 1984, 2003; Vilisics et al. 2007; Schmidt 2008; Hsu et al. 2018). Specific morphological adaptations and behavioral reactions of macrocrustaceans (see below) allowed them to colonize a great variety of arid land habitats (Edney 1968; Lindqvist 1968; Hornung 2011). Many species thrive in

extreme abiotic conditions, such as high-altitude and cold Arctic or sub-Antarctic regions, dry and acidic habitats (Richardson and Jackson 1995; Serejo 2004, 2009; Greenslade et al. 2008; Lowry and Coleman 2012). The highest altitude dwelling crab, *Potamonautes loveni* from Kenya and Uganda lives in terrestrial habitats up to 3060 m a.s.l. (Cumberlidge and Clark 2010), while crabs *Geothelphusa haituan* are known from cloud forests growing at approximately 2000 m a.s.l. in mountains of Taiwan (Chen et al. 2007). Woodlice have been reported from altitudes higher than 4000 m a.s.l., reaching high abundance and density there (Sfenthourakis et al. 2008). The woodlouse *Protracheoniscus nivalis* Verhoeff, 1936 inhabits cloud forests at altitudes reaching 4725 m a.s.l. in Ladakh and an unidentified species was found in mountains of the northwest Himalayas, where oxygen can drop to 60% of the sea-level pressure (Beron 1997, 2008; Hegna and Lazo-Wasem 2010).

Nevertheless, the diversity of ecological niches and biotopes occupied by macrocrustaceans is largely determined by physical environmental factors, such as moisture and temperature. For example, the distribution of woodlice towards the north is limited by the duration of the warm period, and the highest diversity of woodlice on the territory of the former USSR was observed between isoclines of 180 and 210 days with temperature > 10 °C (Kuznetsova and Gongalsky 2012), while the upper limits of temperature tolerance estimated for landhoppers varied between 29.5 °C and 39.5 °C (Gaston and Spicer 1998; Ulian and Mendes 1988; Cowling et al. 2003, 2004). While most terrestrial crustaceans prefer warm conditions, some isopods and amphipods are cold-resistant (Tanaka and Udagawa 1993; Moore et al. 1995; Greenslade et al. 2008). For example, Arctic talitroids of the genus *Orchestia* can survive at temperatures below 0 °C, and even -8 °C (Moore and Francis 1986a, 1986b). The critical relative humidity for most talitroids, below which they show desiccation stress, is close to 95–100%, which makes them dependent on moist leaf litter and soil microhabitats (Lazo-Wasem 1984; Cowling et al. 2003). Synanthropic landhopper *Talitroides topitotum* is considered one of the most tolerant to low humidity but can survive only for 50 h at a relative humidity of 87% (Ulian and Mendes 1988). In contrast, land crab *Holthuisana* (*Austrothelphusa*) *transversa* can survive in arid clay soils of the Australian desert (Greenaway and MacMillen 1978; MacMillen and Greenaway 1978; Waltham 2016), while woodlouse *Hemilepistus reaumurii* inhabits dry loess soils in the Sahara Desert and Negev Desert (Shachak et al. 1976; Dubinsky et al. 1979).

In addition to the forest floor, macrocrustaceans are found in various aboveground habitats, but for many groups such records are still casual. Although most woodlice live in soils and litter layers, some members of the Philosciidae, Armadillidae and Trachelipodidae are arboreal (Paoletti et al. 1991; Paoletti and Hassall 1999). In temperate forests woodlice *Philoscia affinis*, *Philoscia muscorum*, and *Porcellio scaber* are frequently found in the forest canopy, on tree bark, leaves, and branches, not only when the forest floor is inundated or waterlogged (Favretto et al. 1988; Warburg 1993). Arboricolous woodlouse *Atracheodillo marmorivagus* lives on *Carapa grandiflora* in Congo and Rwanda (Schmidt 1999), while South African *Alloniscus marinus* also lives and feeds on green leaves of the bietou bush *Chrysanthemoides* (*Osteospermum*) *monilifera* (Glazier and Kleynhans 2015). *Pseudolaureola atlantica*, endemic woodlouse to St Helena Island, requires the closed canopy and high humidity conditions of black

cabbage tree woodland (*Melanodendron integrifolium*), living an arboreal lifestyle on the fern understorey (Dutton 2017a, b). Arboreal forms are known for talitroids; for example, *Hawaiorchestia gagnei* and *Platorchestia pickeringi* were found in leaf axils of *Freycinetia arborea* well above ground (Richardson 1992). *Allorchestoides rosea* lives among leaves and fibers of the estuarine *Nypa* palm (*Nypa fruticans*) in Thailand (Wongkamhaeng et al. 2018). A truly high diversity of tree-dwelling forms is reached in crabs (Decapoda: Brachyura). Some true crabs, such as Gecarcinucidae (long-legged tree crabs), Potamonautidae, Parathelphusidae, Pseudothelphusidae, and Sesarmidae (so-called "vampire crabs") climb into the crowns of trees but must descend into water reservoirs for reproduction (Schubart et al. 2003, 2009; Cumberlidge et al. 2005; Ng et al. 2015a, 2015b; Wehrtmann et al. 2016; Ng 2017). Some long-legged Asian crabs, e.g., *Calcipotamon*, *Tiwaripotamon*, and *Neotiwaripotamon*, inhabit karstic mountains and massifs where they hide in the water-filled crevices of limestone outcrops, going out at night for feeding in the forest floor (Shih and Do 2014; Do et al. 2016; Huang et al. 2020). Malaysian crabs *Arachnothelphusa merarapensis* and *Arachnothelphusa terrapes* (Ng 1991; Grinang et al. 2015; Ng and Ng 2018) and *Kani maranjandu*, inhabiting holes inside large *Terminalia paniculata* trees in the Western Ghats (Biju Kumar et al. 2017), are fully arboreal, and can even breed in the small water-filled reservoirs in tree hollows (Ng 1995; Ng and Liu 2003). Jamaican *Metopaulias depressus*, one of the most advanced arboreal crabs, is showing features of eusocial behavior, and protect their plants and larvae (Diesel 1989; Diesel and Schuh 1993; Diesel and Schubart 2000, 2007).

Many terrestrial macrocrustaceans are invaders or synanthropes that successfully colonize transformed ecosystems, urban areas, and other anthropogenic habitats such as parks and gardens (Perger et al. 2013; Perger 2014). Woodlice are among the most numerous groups of epigeic arthropods in the transformed habitats (Philpott et al. 2014; Hornung et al. 2015), where the likelihood of successful settlement of invasive species is increased due to suppressed activity of native predators or competitors (Sorensen and Burkett 1977; Szlavecz et al. 2018). From 20% to 90% of species living in transformed habitats of city parks in Japan are represented by terrestrial isopods, mostly invasive species (Lee and Kwon 2015; Giurginca et al. 2017). The most famous invasive landhopper species, *Talitroides topitotum*, formerly endemic to the Indo-Pacific region, is now distributed worldwide through the marketing of exotic plants (Álvarez et al. 2000; Eutrópio and Krohling 2013; Arias-Pineda and Tristancho 2017). Better resistance to drying and the ability to detect and occupy wet shelters in drier habitats allow *Talitroides topitotum* to displace native talitroid species (Friend and Lam 1985; Richardson 1992). Among the invasive talitroids are also *Platorchestia platensis* (Serejo and Lowry 2008; Simpson 2011; Hupało and Grabowski 2018), *Cryptorchestia cavimana* (Konopacka et al. 2009), *Brevitalitrus hortulanus*, *Talitroides alluaudi* (Lincoln 1979; Jazdzewski et al. 2004), and *Arcitalitrus* spp. (Richardson 1980). On the other hand, local communities of native terrestrial crustaceans, especially on isolated oceanic islands, are often affected by various invasive terrestrial invertebrates, such as the predatory nemertean *Geonemertes pelaensis* (Shinobe et al. 2017), the land snail *Lissachatina fulica* (Lake and O'Dowd 1991), and the yellow crazy ant, *Anoplolepis gracilipes* (O'Dowd et al. 2003).

Diversity

The proportion of terrestrial or semi-terrestrial species among different orders of Crustacea varies greatly, and in some lineages might be underestimated. The diversity of terrestrial Branchiopoda (Sousa et al. 2017) and Ostracoda (Pinto et al. 2004, 2005a, 2005b, 2008; Karanovic et al. 2012) is low, represented by only a few species or genera. Approximately 100 terrestrial or semi-terrestrial species have been described in Copepoda, mainly Harpacticoida (Reid 1986, 2001) (Table 2). Overall, terrestrial forms represent < 0.1% of the total diversity of these mainly aquatic taxa. Among macrocrustaceans, ~ 1.7% of the total diversity of order Decapoda (Little 1983; Greenaway 2003), ~ 3% of the order Amphipoda (Hurley 1968; Friend and Richardson 1986; Myers and Lowry 2020), and up to 33% of the order Isopoda (Taiti 2004; Poore and Bruce 2012; Sfenthourakis and Taiti 2015) are presently known as terrestrial species (Table 3). Among the total diversity of terrestrial crustaceans (~ 4,900 species), Branchiopoda and Ostracoda account for 0.1% and 0.6% of all species, respectively. Copepoda, Amphipoda, and Decapoda account for approximately 3.7%, 6.1%, and 7.8%, respectively, while the main diversity (81.6%) belongs to woodlice (Isopoda) (Fig. 1).

Branchiopoda (order Anomopoda) appear to be the least diverse and adapted forms among terrestrial crustaceans and retain a mostly ancestral aquatic lifestyle. Currently, only five species from three genera are reported as semi-terrestrial (Table 2), living in wet mosses growing in primary cloud/rain forests of New Zealand, Cameroon, Puerto Rico, and Venezuela, and wet soils of Cerrado biotopes in Brazil (Frey 1980; Cammaerts and Mertens 1999; Chiambeng and Dumont 1999; Sousa et al. 2017).

The list of terrestrial Ostracoda presently consists of > 30 species from 12 genera, known from leaf litter and wet mosses of tropical and subtropical forests, the spray zone of waterfalls (Martens et al. 2004; Pinto et al. 2004, 2005a, 2005b, 2008; Karanovic et al. 2012), and some coastal habitats, such as coastal wood and algae deposits in Kuril Islands (Schornikov 1969). These genera represent several unrelated lineages adapted to the terrestrial lifestyle, but their phylogeny and zoogeography are still poorly understood.

The known diversity of terrestrial and semi-terrestrial Copepoda includes 18 harpacticoid and 10 cyclopoid genera found in soil, leaf litter, and other moist habitats in tropical and temperate zones worldwide (Reid 1986, 1993, 2001; Dumont and Mass 1988; Corgosinho et al. 2017). Records of these animals in terrestrial habitats are rare and irregular, although thorough studies of soil biota often revealed a greater diversity than could be expected (Fiers and Ghenne 2000; Fiers and Jocque 2013).

The diversity of terrestrial Amphipoda, or sand- and landhoppers (Talitroidea) includes ~ 300 described species from seven families with at least 125 genera (Table 3) inhabiting various terrestrial, intertidal, and supralittoral habitats from sandy beaches to leaf litter of lowland and highland forests worldwide (Serejo and Lowry 2008; Lowry and Myers 2019; Myers and Lowry 2020).

Table 2. Taxa with terrestrial or semi-terrestrial forms among microcrustaceans (Branchiopoda, Ostracoda, Copepoda).

Families	Genera
Branchiopoda (Cladocera), order Anomopoda (3 genera)	
Chydoridae	*Bryospilus*, *Nicsmirnovius*, *Monospilus*
Ostracoda, order Podocopida (12 genera)	
Cypridídae	*Austromesocypris*, *Bryocypris*, *Callistocypris*, *Mesocypris*, *Scottia*
Candonidae	*Caaporacandona*, *Terrestricandona*, *Terrestricypris*
Limnocytheridae	*Intrepidocythere*
Terrestricytheridae	*Terrestricythere*
Darwinulidae	*Penthesilenula*, *Vestalenula*
Copepoda, order Harpacticoida (18 genera)	
Parastenocarididae	*Remaneicaris*, *Forficatocaris*, *Murunducaris*
Canthocamptidae	*Canthocamptus*, *Bryocamptus*, *Epactophanes*, *Fibulacamptus*, *Maraenobiotus*, *Moraria*, *Gulcamptus*, *Remaneicaris*, *Pindamoraria*, *Eirinicaris*, *Elaphoidella*, *Attheyella* (*Chappuisiella*), *Antarctobiotus*
Phyllognathopodidae	*Phyllognathopus*, *Parbatocamptus*
Copepoda, order Cyclopoida (10 genera)	
Cyclopidae	*Bryocyclops*, *Virbiocyclops*, *Paracyclops*, *Goniocyclops*, *Graeteriella*, *Ectocyclops*, *Menzeliella*, *Metacyclops*, *Muscocyclops*, *Olmeccyclops*

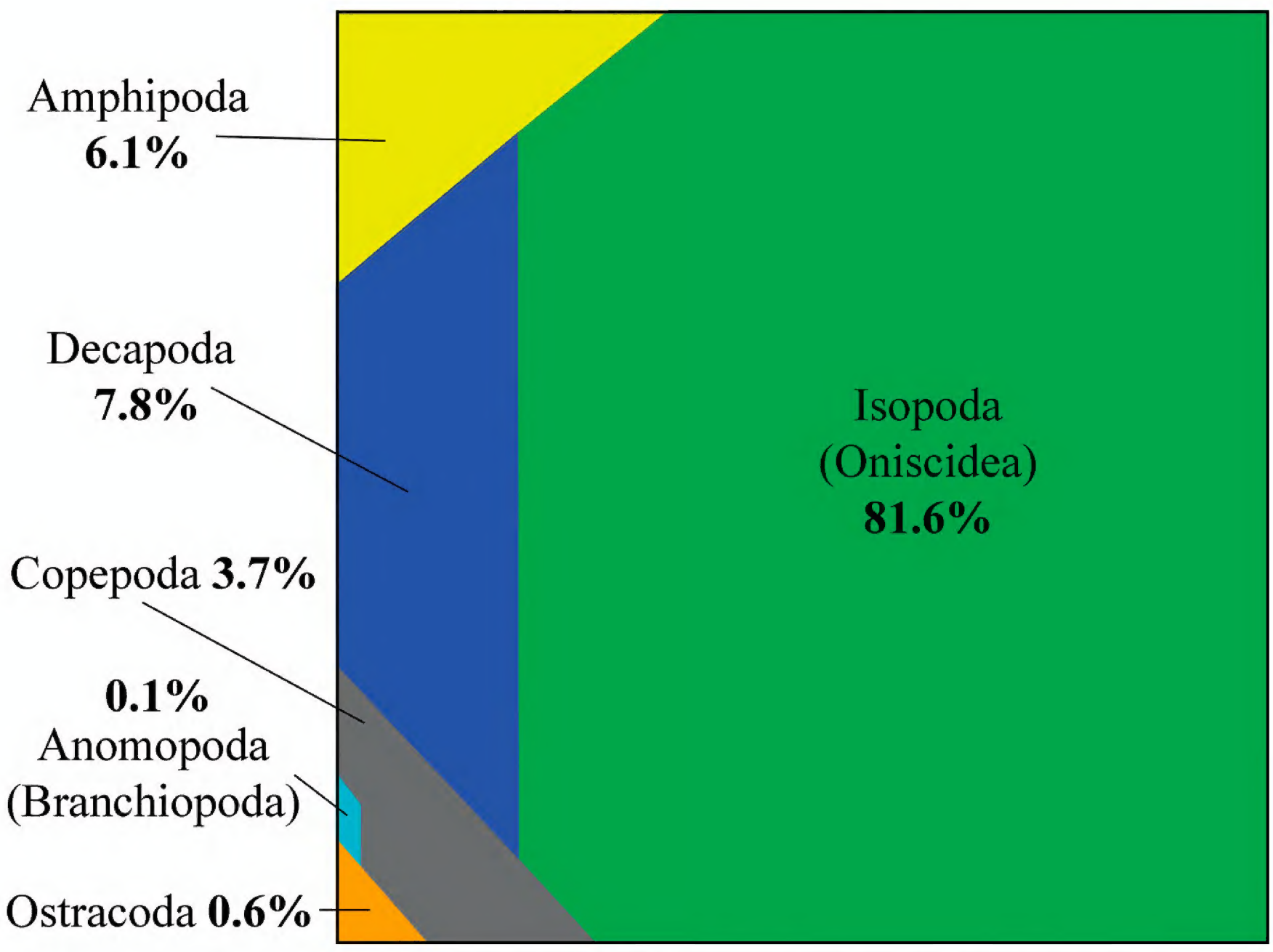

Figure 1. Proportions (%) of all known species of terrestrial Crustacea among different lineages (orders).

Table 3. Taxa with terrestrial or semi-terrestrial forms among macrocrustaceans (Malacostraca).

Superfamilies or families	Families or genera
Order Amphipoda (125+ genera)	
Superfamily Talitroidea	Arcitalitroidae (15 genera), Protorchestiidae (6 genera), Uhlorchestiidae (1 genus), Brevitalitroidae (8 genera), Curiotalitroidae (1 genus), Makawidae (22 genera), Talitroidae (72 genera)
Order Isopoda (554+ genera)	
Suborder Oniscidea	Agnaridae (14 genera), Alloniscidae (1 genus), Armadillidae (81 genera), Armadillidiidae (16 genera), Balloniscidae (2 genera), Bathytropidae (7 genera), Berytoniscidae (1 genus), Bisilvestriidae (1 genus), Cylisticidae (4 genera), Delatorreiidae (3 genera), Detonidae (3 genera), Dubioniscidae (3 genera), Eubelidae (50 genera), Halophilosciidae (3 genera), Hekelidae (1 genus), Irmaosidae (1 genus), Ligiidae (6 genera), Mesoniscidae (1 genus), Olibrinidae (5 genera), Oniscidae (6 genera), Oniscidea incertae sedis (30 genera), Paraplatyarthridae (1 genus), Philosciidae (115 genera), Platyarthridae (8 genera), Porcellionidae (19 genera), Pudeoniscidae (4 genera), Rhyscotidae (2 genera) Schoebliidae (1 genus), Scleropactidae (28 genera), Scyphacidae (6 genera), Spelaeoniscidae (9 genera), Stenoniscidae (3 genera), Styloniscidae (17 genera), Tendosphaeridae (3 genera), Titanid ae (5 genera), Trachelipodidae (8 genera), Trichoniscidae (87 genera), Turanoniscidae (1 genus), Tylidae (2 genera)
Suborder Phreatoicidea	Phreatoicidae (1-2 terrestrial genera)
Order Decapoda (most mangrove mud-dwelling and costal crabs are excluded)	
Infraorder Astacidea (5 genera)	
Cambaridae	*Distocambarus* (= *Fitzcambarus*)
Parastacidae	*Engaeus*, *Euastacus*, *Parastacus*, *Virilastacus*
Infraorder Caridea (1 genus)	
Merguiidae	*Merguia*
Infraorder Anomura (2 genera)	
Coenobitidae	*Birgus*, *Coenobita*
Infraorder Brachyura (73+ genera)	
Gecarcinidae	*Cardisoma*, *Discoplax*, *Gecarcinus*, *Gecarcoidea*, *Johngarthia*, *Tuerkayana*
Gecarcinucidae	*Arachnothelphusa*, *Ceylonthelphusa*, *Holthuisana* (*Austrothelphusa*), *Sayamia*, *Sundathelphusa*, *Terrathelphusa*, *Thelphusula*
Grapsidae	*Geograpsus*, *Goniopsis*, *Metopograpsus*
Parathelphusidae	*Esanthelphusa*, *Oziotelphusa*, *Parathelphusa*, *Perbrinckia*
Potamidae	*Binhthuanomon*, *Calcipotamon*, *Candidiopotamon*, *Carpomon*, *Chinapotamon*, *Dromothelphusa*, *Gempala*, *Geothelphusa*, *Indochinamon*, *Johora*, *Krishnamon*, *Nanhaipotamon*, *Neotiwaripotamon*, *Phaibulamon*, *Pudaengon*, *Qianguimon*, *Rathbunamon*, *Ryukyum*, *Socotra*, *Somanniathelphusa*, *Thaiphusa*, *Thaipotamon*, *Tiwaripotamon*
Potamonautidae	*Globonautes*, *Liberonautes*, *Madagapotamon*, *Malagasya*, *Potamonautes*, *Sudanonautes*
Pseudothelphusidae	*Epilobocera*, *Guinotia*, *Ptychophallus*
Sesarmidae	*Aratus*, *Armases*, *Chiromantes*, *Episesarma*, *Geosesarma*, *Geosesarmamirum*, *Haberma*, *Karstama*, *Labuanium*, *Metasesarma*, *Metopaulias*, *Neosarmatium*, *Parasesarma*, *Perisesarma*, *Scandarma*, *Sesarmoides*, *Sesarmops*, *Selatium*, *Tiomanium*
Trichodactylidae	*Trichodactylus*
Varunidae	*Chasmagnathus*

Isopoda are the most advanced, adapted, and successful land colonizers presented by the cosmopolitan suborder Oniscidea (woodlice). Oniscidea include ~ 40 families with ~ 552 genera and ~ 4,000 described species, while an estimated diversity is close to 5,000–7,000 extant species (Schmalfuss 2003; Javidkar et al. 2015; Sfenthourakis and Taiti 2015). Due to their wide distribution, diversity, and high abundance, woodlice are the best-studied terrestrial crustaceans. In addition, there are several semi-terrestrial burrowing species of the genus *Phreatoicopsis* (Phreatoicidea: Amphisopodidae) known from wetlands or swamps of the Grampians National Park, Australia (Spencer and Hall 1896; Wilson and Keable 2002).

Terrestrial and semi-terrestrial Decapoda are represented by four infraorders: Reptantia (crayfish) (~ 60 species), Anomura (hermit crabs) (~ 18 species), Caridea (shrimp) (2–4 species), and Brachyura (crabs) (~ 300 species) (Table 3). Terrestrial representatives of Reptantia are limited to some members of the Cambaridae and Parastacidae, living in damp soils and nearly completely independent of surface waters. The evolution of terrestriality is especially characteristic of the genera *Engaeus* (> 35 species), some *Euastacus* and *Cherax* species from Australia and Tasmania, *Parastacus* (> 14 species) and *Virilastacus* (4 species) from South America (mainly Chile), and *Distocambarus* (= *Fitzcambarus*) (4 species) from the southeastern USA (Georgia/North Carolina) (Horwitz 1990; Furse and Wild 2002; Rudolph and Crandall 2012; Reynolds et al. 2013; McCormack and Raadik 2021). Most of these crayfish build deep and complex burrows that are not associated with permanent water reservoirs (Welch and Eversole 2006). They spend their entire life cycle inside the burrows feeding on roots and leaves, collecting the latter from the soil surface, and making frequent excursions from the burrows at night or after rain floods or snowmelts, as do *Fallicambarus* (*Creaserinus*) *fodiens* (Decapoda: Cambaridae) in the USA and Canada (Suter and Richardson 1977; Growns and Richardson 1988; Richardson and Swain 1990; Norrocky 1991; Guiaşu 2007; Graham et al. 2022). Infraorder Anomura is represented in terrestrial habitats by hermit crabs of the family Coenobitidae, including the genus *Coenobita* (> 17 species) and the coconut crab *Birgus latro* (Rahayu et al. 2016). Among Caridea, two shrimp species of the genus *Merguia* (Merguiidae) show a semi-terrestrial lifestyle, inhabiting fringe or riverine mangrove swamps and climbing tree trunks at night during the low tides (Abele 1970; Vannini and Oluoch 1993). In addition, two species of the genus *Potamalpheops*, the Asian *P. kisi*, and the Australian *P. hanleyi*, were also found in semi-terrestrial habitats of mangrove forests (Bruce 1991; Marin 2021). The highest grades of adaptations to terrestrial lifestyle within the Brachyura are realized in Gecarcinidae (> 20 species), Sesarmidae (> 250 species), and some representatives of Gecarcinucidae, Potamidae, Gecarcinidae, Potamonautidae, Pseudothelphusidae, and Trichodactylidae (Bright and Hogue 1972; Biju Kumar et al. 2017; Ng and Ng 2018); although the term "land crab" is often used to mean solely the representatives of the family Gecarcinidae (Burggren and McMahon 1988; De Grave et al. 2009).

We would like to devote a separate paragraph to peculiar records of crustaceans in soil communities, which seem unusual even in the light of this review. In addition to Talitroidea, several amphipod species of genera *Niphargus* and *Microniphargus* (Niphargidae) have been reported from soil habitats (Lagidze et al. 1974; Turquin 1983; Hudec et al. 2017). *Niphargus talikadzei*

was described as "the first true soil-dwelling *Niphargus* species" (Lagidze et al. 1974) from Georgia (Caucasus), an extremely aberrant species *Niphargus rhenorhodanensis* from interstitial and soil capillary cavities in France (Mathieu et al. 1994), while several *Microniphargus* species have been occasionally recorded in soil samples in Ireland (Arnscheidt et al. 2008, 2012). The Amphipod *Rudolphia macrodactylus* (Paraleptamphopidae) was described from the soil burrows of semi-terrestrial crayfish *Virilastacus rucapihuelensis* (Parastacidae) and surrounding peat bogs in Chile (Grosso and Peralta 2009). A tiny amphipod of the genus *Palearcticarellus* (Crangonyctidae) has also been recorded from a wet moss around springs in the Kurai highland valley (steppe) in Altai, Russia, but not in the spring itself, where they were likely preyed upon by larger species of the genus *Gammarus* (Palatov and Marin 2020). Even more strange is the record of Branchiopoda in soil samples (Battigelli et al. 1994). All these animals are characteristic of small epigean (Brachiopoda) or subterranean (Niphargidae) water reservoirs (e.g., Fišer 2019), and probably should not be considered as true soil inhabitants, although our knowledge of the biology of these crustaceans is still strongly limited.

Abundance (density and biomass)

Terrestrial crustaceans can reach high densities and abundance (Table 4), although for some groups, namely Brachiopoda (Anomopoda) and Ostracoda, such data are not yet available. Small-sized Copepoda, mainly harpacticoids, were reported to be "surprisingly abundant" in many terrestrial and semi-terrestrial habitats (Plowman 2006; Fiers and Ghenne 2000; Reid 2001; Reid and Rocha 2003), reaching up to 3% of all sampled animals (Battigelli et al. 1992; Fiers 2013). The density of Copepoda (54,400–93,600 ind/m^2) was comparable to that of most abundant soil microarthropods, i.e., Acari (38,600–189,000 ind/m^2) and Collembola (34,800–140,300 ind/m^2) in the wet cedar-hemlock forest in British Columbia (Battigelli et al. 1992). The biomass of these animals has been rarely measured. Schaefer and Schauermann (1990) reported a dry mass of harpacticoids of ~ 0.6–2.0 mg/m^2 in two beech forests in Germany with a density of 3,900–3,300 ind/m^2. Based on recorded densities, the biomass of microcrustaceans can be much higher in some habitats.

Terrestrial Amphipoda and Isopoda are medium-sized arthropods (typically ≤ 30 mm in body length and dry weight not exceeding 50–70 mg). Their abundance and biomass can be comparable to those of millipedes and other co-dimensional representatives of soil macrofauna (David et al. 1999; Messelink and Bloemhard 2007; David and Handa 2010) (Table 4). The highest known biomass is reported for the desert woodlouse *Hemilepistus reaumurii* (~ 20 kg/ha with a population density of ~ 50 ind/m^2), which is comparable to the combined biomass of desert mammals (~ 40 kg/ha) in the same habitats (Markwiese et al. 2001). This impressive statistic can be somewhat overestimated as it reflects densities of woodlice aggregations observed at the microhabitat scale (Broly et al. 2012).

Terrestrial Decapoda also achieve significant abundance, as well as the highest values of biomass among terrestrial arthropods, also being the heaviest of all terrestrial arthropods. In particular, the robber crab *Birgus latro* is the largest terrestrial arthropod, reaching 1 m in length from leg to leg and ~ 12 cm in width

Table 4. The maximum known abundance (density or biomass) of terrestrial crustaceans.

Species or taxa	Habitat	Abundance	Reference
Microcrustacea			
Harpacticoid copepods, probably one species	Beach forests in Germany	3,300–3,900 ind/m^2 0.6–2.0 mg d.wt./m^2	Schaeffer and Schauermann 1990
Copepoda	Conifer subalpine forest in France	3,700 ind/m^2	Bernier and Gillet 2012
Different harpacticoids	Canadian tundra	>6,500 ind/m^2	Bliss et al. 1973
Harpacticoid *Forficatocaris schadeni*	Wet campo marshes of central Brazil	>178,000 ind/m^2	Reid 1982
Copepoda, mainly harpacticoids	Wet cedar-hemlock forest in British Columbia	>54,400–93,600 ind/m^2	Battigelli et al. 1992
Macrocrustacea			
Landhoppers (Amphipoda: Talitroidea)			
Makawe hurleyi	New Zealand forests	1230–2670 ind/m^2	Duncan 1994
Several syntopic talitroids	Tasmanian forests	>10,000 ind/m^2	Friend and Richardson 1987
Allorchestes compressa	The coast of Western Australia	110 ind/g of algae remnants	Lenanton et al. 1982
Bellorchestia quoyana (= *Talorchestia quoyana*)	Coastal sand beaches in New Zealand	11.8 g/m^2	Marsden 1991
Woodlice (Isopoda: Oniscidea)			
Woodlice	Temperate forests	35–630 ind/m^2	Topp et al. 2006
Atlantoscia floridana	Semi-deciduous forest of Southern Brazil	1040 ind/m^2	Araujo and Bond-Buckup 2005
Woodlice	Calcareous grasslands	800–3000 ind/m^2	Paoletti and Hassall 1999; Gongalsky et al. 2005
Porcellio scaber	Northern France	5070 ind/m^2 in aggregations	Broly et al. 2016
Desert woodlice *Hemilepistus reaumurii*	Deserts of Northern Africa	50 ind/m^2 and 2 g/m^2 in aggregations	Markwiese et al. 2000
Syntopic *Atlantoscia floridana* + *Balloniscus glaber*	Semi-deciduous forest of Southern Brazil	2.56 g/m^2	Quadros and Araujo 2008
Woodlice	Temperate forests	0.09–0.35 g/m^2	White 1968
Crabs and hermit crabs (Decapoda)			
Gecarcinus quadratus	Mainland forests of Costa-Rica	0.8–6 ind/m^2	Sherman 2002, 2003; Lindquist and Carroll 2004; Lindquist et al. 2009
Birgus latro	Christmas Island	41–166 ind/ha	Rumpff 1986; Schiller 1988
Gecarcinus lateralis	Tropical semi-deciduous forests of Central America and Florida	1–3 ind/m^2 and 2 burrows/m^2	Bliss et al. 1978; Britton et al. 1982; Delfosse 1990; Kellman and Delfosse 1993
Gecarcoidea natalis	Christmas Island	1.3–2.6 ind/m^2 (migrations) and 1.8 burrows/m^2, with the estimated peak biomass close to 113.7–145.4 g/m^2	Hicks 1985; O'Dowd and Lake 1991; Green et al. 1997; Adamczewska and Morris 2001
Cardisoma crassum	Mexico	the average density 1.66 burrow/m^2	Vázquez-López et al. 2014

Species or taxa	Habitat	Abundance	Reference
Cardisoma guanhumi	Venezuelan coastline and Florida	5.48 burrows/m^2 (Venezuella) and ≥ 200 g/m^2 (Florida)	Gifford 1962; Green 1997; Carmona-Suárez 2011
Gecarcinus planatus	Clipperton Atoll	up to 6 ind/m^2	Ehrhardt and Niaussat 1970; Turkay 1973; Wolcott 1988
Coenobita rugosus	Andaman Coast of Thailand	up to 8.4 ind/m^2	Bundhitwongrut et al. 2014
Coenobita clypeatus	Bahamian islands	~ 14.3 crabs/m^2	Morrison and Spiller 2006
Sympatric *Coenobita* spp.	Vegetated area of Bahamian islands	46 ind/m^2 in dense agglomerations	Morrison and Spiller 2006
Uca annulipes	Coastal habitats of East Africa	175 ind/m^2	Skov et al. 2002

of the carapace with a weight of up to 4.0 kg (Brown and Fielder 1991; Drew et al. 2010, 2013). With a relatively large size (2–12 cm of carapace width and weight occasionally > 500 g) and a density often exceeding 1 ind/m^2, the total biomass of land crabs can reach 1000 kg/ha and higher, especially during the annual breeding migrations (see below). In tropical island and inland forests, the biomass of terrestrial decapods released in the absence of natural enemies and competitors (Green 1997; Lindquist et al. 2009), can exceed the total biomass of animals reported in tropical rain forests in Costa Rica (115 kg/ha; Odum et al. 1970) and the central Amazon (210 kg/ha; Fittkau and Klinge 1973) (Table 4).

Summarizing, both micro- and macrocrustaceans are widely distributed in terrestrial environments, with the greatest diversity and abundance in warm and humid habitats, such as tropical and subtropical coastal forests. Large Decapoda species reach the maximum density and biomass on well-isolated tropical islands, which should be likely ascribed to the absence of competitors and predators, like mammals and forest birds. Medium-sized landhoppers and especially woodlice are acknowledged components of soil macrofauna in temperate and even subarctic ecosystems. Tiny harpacticoid and cyclopoid copepods are common members of the soil mesofauna and possibly occupy more ecological niches than is usually assumed, but their density and biomass are still underestimated.

Additional literature on the topic

Diversity, distribution, and evolution of woodlice are reviewed in Edney (1954), Warburg (1993), Sfenthourakis et al. (2004, 2020), Loureiro et al. (2005), and Hornung (2011); talitroids in Richardson and Swain (2000), terrestrial crabs in Burggren and McMahon (1988), crayfish in Reynolds et al (2013), and anomurans in Greenaway (2003).

Adaptations to a terrestrial lifestyle

The transition from aquatic habitats to a terrestrial lifestyle required numerous adaptations in morphology, respiratory physiology, osmoregulation and water balance, excretion, respiration, sensory perception, thermoregulation, molting, reproduction, and behavior. Terrestrial crustaceans are in general morphologically similar to their aquatic ancestors, with morphological pre-adaptations to

the terrestrial lifestyle differing in the main lineages. These adaptations can be categorized into five classes ranging from T1 (lowest) to T5 (highest) depending on the degree of independence from immersion in water and the need for access to water for breeding (Powers and Bliss 1983), although this classification is currently rarely used. Schubart et al. (2000) proposed an alternative system that includes three simplified degrees of terrestriality as follows: (A) terrestrial adults with marine larvae, (B) limnic-terrestrial adults (spend most of their lives in or near freshwater) with marine larvae, and (C) adults that breed in inland waters and hence are independent from the ocean. This classification is based on the paths of land penetration, which are reflected in the modern biology and ecology of crustaceans. Taxa derived from the marine environment must release larvae into the sea, returning to the mainland as the last zoea/megalopa stages, while taxa of freshwater origin mostly have reduced or abbreviated development and can live in terrestrial habitats far from the sea coastline (Wolcott 1988).

Studies on the mechanisms of terrestrialization rarely concern microcrustaceans, which have a very limited set of specific adaptations (e.g., Cammaerts and Mertens 1999; Chiambeng and Dumont 1999). Therefore, most examples below are representatives of macrocrustaceans.

Morphological adaptations

Air-breathing structures and cuticle

Adaptations for air-breathing and preventing evaporation, a prerequisite for the terrestrial lifestyle, are represented by pleopodal lungs, or “pseudotrachea”, in woodlice, ancestrally derived from pleopodal gills, which can be conditionally categorized into three types: dorsal respiratory fields, uncovered, and covered lungs (Schmidt and Wägele 2001; Paoli et al. 2002; Hornung 2011; Csonka et al. 2013; Ernst et al. 2020; Sfenthourakis et al. 2020). Similar structures are presented on the abdomen and posterior surface of the carapace in terrestrial hermit crabs (Morris 2002; Farrelly and Greenaway 2005). Because the water content is related to the body mass, and water loss is proportional to the body surface, the loss of water through pleopods is most critical for small-size species, while larger species lose relatively less water through their pleopods and cuticle. Passive respiration using pleopods (in contrast to abdominal/branchiostegal lungs in Decapoda or tracheae in Insecta; Schmidt and Wägele 2001; Garwood and Edgecombe 2011) and the need to enforce the thin cuticle ensured further ecological diversification in woodlice. A trend of gill reduction is also described in talitroids (Moore and Taylor 1984; Richardson 1998). Despite elaborate adaptations, land-dwelling woodlice and talitroids are still feebly protected from desiccation, primarily due to the absence of waxy cuticle (Hadley and Quinlan 1984). The presence of specific epicuticular lipids reduces water loss due to evaporation in woodlice of the genera *Buddelundia* (arid regions of Australia), *Hemilepistus* (Sahara and Negev deserts), and especially in *Venezillo arizonicus* (Arizona desert) (Cloudsley-Thompson 1956, 1975, 1988; Warburg 1965a, 1965b). Furthermore, some woodlice possess air-breathing organs remarkably similar to tracheae in insects that expand and enter the thoracic body trunk (see Ferrara et al. 1997).

Terrestrial hermit crabs have developed specific abdominal lungs, a vascular network in the thin dorsal integument of the abdomen (Farrelly and Greenaway 2005), while the number of gills and their area decreases with increasing terrestriality in brachyuran crabs (Farrelly and Greenaway 1992, 1993, 1994; Greenaway 1999). The most advanced coconut crab *Birgus latro* has markedly reduced gills, while gas exchange mostly occurs in specific respiration structures (branchiostegal and abdominal lungs) (Greenaway et al. 1988; Farrelly and Greenaway 2005), represented by vascular casts protruding into an aerial chamber, resulting in a large surface area. The diffusion barrier in these structures is shorter and hemolymph from the lungs goes directly to the pericardial sinus; this species also has the highest blood pressure (50 mm Hg) among crustaceans (Greenaway et al. 1988, 1990; Greenaway 2001). The usage of a protective gastropod shell in land hermit crabs favored the evolution of the abdominal lung, while the rejection of this heavy shell by *Birgus latro* also stimulated the development of branchiostegal lungs, which allowed effective colonization of terrestrial and even arboreal habitats (Greenaway 2003; Farrelly and Greenaway 2005). The cuticle of the gill lamellae of almost all air-breathing terrestrial decapods is usually much thicker than that of their aquatic relatives (Taylor and Taylor 1992). The surface of the gills of most terrestrial brachyurans can also be increased by various morphological structures, ranging from the thickening of the marginal canal (*Cardisoma hirtipes*), marginal nodular swellings (*Geograpsus grayi*) (Farrelly and Greenaway 1992), and vascular casts decorating the gill and branchial chamber surface (*Gecarcoidea natalis* and *G. lalandii*) (Cameron 1981; Farrelly and Greenaway 1992; Morris and De-la-Cruz 1998; Morris 2002). Terrestrial grapsid and gecarcinid crabs also have highly developed lung-like structures in addition to their gills, increasing the surface area for gas exchange (Farrelly and Greenaway 1993).

Land crabs and hermit crabs also have physiological changes in the respiratory organs. For example, they have developed a double circulation of hemolymph either through the lungs or through the gills. In addition, one of the functions of the gills in the aquatic environment, namely the exchange of salt and ammonia with water, does not work in terrestrial species, which contributed to the development of other physiological adaptations.

Body size

The body size of terrestrial crustaceans does not obey most known biological rules (Karagkouni et al. 2016a, b), except for the above-mentioned relationships with the evaporation intensity. In smaller macrocrustaceans such as landhoppers and woodlice, body size reduction can be considered as an adaptation to living in narrow spaces (Loureiro et al. 2005; Hornung 2011). A positive correlation between body size and latitude is observed in terrestrial crustaceans in arid habitats and partly in a temperate climate (Karagkouni et al. 2016a, b). On the other hand, the terrestrial hermit crab *Birgus latro*, living on tropical Indo-West Pacific oceanic islands with a warm and humid climate, is one of the largest present-day arthropods (Drew et al. 2010, 2013). Tropical South American gecarcinids, *Cardisoma guanhumi*, and *C. crassum*, the largest known forest-dwelling crab species, can reach a maximum width of the carapace of 130 mm and a weight of 500 g (Ehrhardt and Niaussat 1970; Pérez-Chi

2005), while *Tuerkayana hirtipes* from Andaman Islands have a weight of up to 600 g (Alcock 1900; after Green 1997). A wide range of predators apparently preys upon smaller talitroids and woodlice, so that the island environment does not exert strong selection pressure on their body size (Karagkouni et al. 2016a).

It is also worth mention here that an important ecological advantage of crustaceans over other terrestrial arthropods is the growth throughout life and the ability to regenerate limbs, whereas the molting process and subsequent calcification represent an extremely vulnerable stage of their life cycle.

Limbs and mobility

Life on land is impossible without the ability to move using principles very different from those used in the water. Most true terrestrial crustaceans are not able to swim as adults and may drown in the water, while they can crawl in a moist environment. Nevertheless, their ability to move over land is determined by the morphology of their aquatic ancestors.

Terrestrial brachiopods (cladocerans) differ from their aquatic relatives by reduced antennae and eyes, stronger armored (spinulated) limbs and the presence of robust teeth on their post-abdominal claw (Cammaerts and Mertens 1999; Chiambeng and Dumont 1999; Sousa et al. 2017).

Terrestrial ostracods also hardly differ in morphology from their aquatic relatives, except for the progressive loss of swimming setae, whereas the second pair of antennae became strong. Together with the fusion of some segments, this makes the limbs better suitable for crawling. This can be considered as a specific adaptation to terrestrial habitats, characteristic of non-related lineages (genera) (De Deckker 1983; Powers and Bliss 1983; Martens et al. 2004; Pinto et al. 2008). All known soil- and leaf litter-dwelling copepods have elongated worm-like bodies, especially typical of canthocamptids that allow them to creep in narrow pores in moist edaphic habitats (Fiers 2013). Diapausing highly protected eggs and cysts produced by Copepoda and Ostracoda allow them to cross wide areas of the land with the help of wind or vertebrates (Vogt 2016; Glime 2017a).

Terrestrial talitroids (Talitroidea) do not move very fast on the ground, but they walk efficiently upright, as well as jump like fleas, which helps to avoid predators (Bracht 1980; Wan and Gorb 2021). The body-catapult mechanism of *Talitrus saltator*, consisting of the arc-shaped structures at the leading edge of the five posterior segments, having fibrous microstructures along it in a circumferential direction and containing a large amount of elastic tissue and a small amount of chitin, can accumulate a large amount of energy to enhance the force of the jump. It has an output power of ~ 1.7–5.7 kW/kg, which is 3.4–11.4 times higher than the limit of the output power of muscles of other arthropods (Wan and Gorb 2021). Woodlice reflexively move faster in dry conditions (unfavorable environments) and slower in wet ones (Fraenkel and Gunn 1961). In addition, woodlice show thigmokinesis, meaning they stop moving when they are close to a solid object, including other individuals, so they often form clusters in humid microsites (Friedlander 1964; Sutton 1972).

Terrestrial crabs are well adapted for fast movement to escape predators, for example, the semi-terrestrial Hawaiian ghost crab *Ocypode ceratophthalmus* is among the fastest known wingless land invertebrates reaching running speed of 3 m sec^{-1} (Burrows and Hoyle 1973; Florey and Hoyle 1976). Unusually long legs

of forest crabs of the family Gecarcinucidae allow them to climb trees (Grinang et al. 2015; Biju Kumar et al. 2017; Ng and Ng 2018), and efficiently move along the outcrops of karst massifs (Shih and Do 2014; Do et al. 2016; Huang et al. 2020).

Sensory organs (thermal, humidity, olfactory, and visual sensitivity)

Woodlice and talitroids have effective temperature and humidity receptors allowing them to select warm or wet habitats or to avoid extreme temperatures and dry areas (Warburg 1964, 1968, 1993; Morritt 1998; Lagerspetz and Vainio 2007). Some woodlice have specific temperature-sensitive neurons that respond to evaporative heat loss and humidity (Schmalfuss 1998; Hornung 2011). The sensitivity of antennae to temperature may depend on local water loss from thin-walled structures, which probably contain mechanosensory neurons (Sutton 1972, 1980; Hallberg and Skog 2011; Schmidt and Mellon 2011). It is assumed that the antennae, as well as the tritocerebral processing structures associated with them, partially compensate for the loss or significant reduction of the (deutocerebral) primary olfactory pathway in terrestrial talitroids and oniscids (Krieger et al. 2021).

Although the morphological structure of antennae in coenobitid hermit crabs is completely similar to the structure of the chemoreceptive organs of related aquatic species (Ghiradella et al. 1968a, 1968b), their olfactory lobes in the brain are significantly increased compared to their aquatic relatives (Krång et al. 2012; Polanska et al. 2020; Krieger et al. 2021). *Coenobita compressus* can detect odors of feces, fruit, and fish from a distance of at least 5 m by detecting volatile chemical signals and can detect non-volatile compounds using contact chemoreception (Rittschof and Sutherland 1986; Dunham and Gilchrist 1988). Acetoin from coconut and arenga fruit was the only one of the 15 volatile compounds tested that attracted omnivorous robber crab *Birgus latro* (Knaden et al. 2019), which has an olfactory system similar to that of insects (Stensmyr et al. 2005). In contrast, terrestrial talitroids, woodlice, and crabs have reduced and miniaturized antennae and olfactory aesthetascs, as well as primary olfactory processing brain centers, suggesting a loss of olfaction during the evolution on land (Kuenen and Nooteboom 1963; Krieger et al. 2015, 2021).

Terrestrial crabs and hermit crabs typically have well-developed visual neuropiles and neuronal substrates for a sophisticated analysis of the compound eye input. Vision plays an important role in their behavior such as food and habitat search, mating, and orientation (Krieger et al. 2015; Chou et al. 2020). The fiddler crabs of the genus *Uca* can distinguish colors (Detto 2007; Jordão et al. 2007) and possesses ultraviolet and polarization vision (Detto and Backwell 2009; How et al. 2012), which is an important factor for their orientation and social interactions (Detto et al. 2006; Detto 2007). The visual system of *Coenobita* is separated into peripheral and central viewing areas (Ping et al. 2015).

Physiological adaptations

Feeding and digestion

Crustaceans are primarily detritophages or herbivores, with the feeding objects ranging from small organic particles extracted from soil to leaf litter, seeds, flowers, and fruits. The problems associated with a low-quality plant

diet can potentially be avoided by selecting the most palatable food items. To improve energy efficiency, crustaceans can supplement a plant-based diet with animal tissues, but only a few species became carnivorous. Other trophic strategies of crustaceans include low intake rates, longer retention of digesta, and efficient assimilation of structural carbohydrates (Linton and Greenaway 2007). Many species, especially small-sized macrocrustaceans, are omnivorous and respond to spatial and temporal changes in the quality or quantity of food resources by changing their activity and feeding tactics, including coprophagy (Hassall and Rushton 1982). Effective mechanical crushing of coarse plant material is necessary to increase the surface of the food substrate exposed to digestive enzymes (Johnston et al. 2005). All crustaceans have powerful jaws for the initial crushing of plant material; after swallowing the pieces are further crushed by a gastric mill (Linton and Greenaway 2004). Active cellulases and laminarinases have been identified in the digestive juice, gut, and midgut gland or hepatopancreas of a wide variety of crustacean species allowing them to hydrolyze cellulose and hemicellulose to their constituent sugars (reviewed in Linton and Greenaway 2007). Lichenase and xylanase have been less studied but are present in the digestive juice and may be common in Crustacea (Linton and Greenaway 2004). Isopods depend on the hydrolases of microorganisms (Kozlovskaya and Striganova 1977), including fungal enzymes such as xylanase and cellulase (Kukor and Martin 1986). The dependence of woodlice on the microbial activity of leaf litter, measured in terms of cellulase activity, has been repeatedly demonstrated (Uesbeck and Topp 1995; Zimmer and Topp 1997).

Water balance and osmoregulation

The tolerance to desiccation is not likely to be the most important factor contributing to the success of macrocrustaceans in terrestrial habitats (Lazo-Wasem 1984; Moore and Francis 1985). The absence of any specific physiological adaptation in osmoregulation suggests that they were not subjected to the great desiccation stress during the evolution, since otherwise one would expect some capacity to deal with hyperosmotic stresses caused by desiccation (Morritt 1988). The osmotic pressure of the hemolymph and exosomatic fluid (400–850 mOs, usually 700–850 mOs) in most terrestrial species are slightly lower than in seawater, although in talitroid *Makawe hurleyi* the mean osmotic pressure of hemolymph is ~ 45% of seawater (Duncan 1985). It was suggested that the lack of ions, especially chloride (Cl-) and sodium (Na+), might restrict the distribution of talitroid species to coastal areas (Spicer et al. 1987; Morritt and Spicer 1998; Richardson et al. 2001a, b, 2003; Cowling et al. 2003, 2004). Water loss due to evaporation over 25% is fatal for beach flea *Orchestia gammarellus* (Moore and Francis 1986b; Morritt 1987), and the threshold of 30% was reported for another species, *Platorchestia platensis* (Garces 1988). However, physiological adaptations related to ion regulation were seemingly more important in the evolution of landhoppers than adaptations to resist the effects of desiccation (Friend and Richardson 1986; Moore and Francis 1986b). Some oniscoids and talitroids can absorb water not through the oral route, but through the cuticle (Hoese 1981, 1982; Moore and Richardson 1992).

Almost all land crabs are restricted to tropical and subtropical humid ecosystems, although they depend not so much on the temperature and humidity of the environment, as on these parameters inside the branchial chamber (Wolcott 1988). Fluctuations in ambient temperature and environmental conditions generally favor evaporative water loss, due to increased metabolism (Weinstein 1998). The semi-terrestrial potamonid crab *Sudanonautes africanus* from wet rain forests of West Africa tolerates water loss of ≤ 20% of body weight (34% of total body water) (Lutz 1969) and coastal hermit crab *Coenobita brevimanus* up to 28% of total body water (Burggren and McMahon 1981). The Australian desert crab *Austrothelpusa transversa* can lose up to 42% of body weight, having one of the highest rates of water content in tissues among land crabs. Despite these features, the crab can only survive ~ 90 h at a relative humidity of 70% (rH) and 20 °C (MacMillen and Greenaway 1978; Greenaway and MacMillen 1978; Burggren and McMahon 1981). Of the other land crabs studied, only *Gecarcinus lateralis* can tolerate a similar to *Austrothelpusa transversa* degree of weight loss (< 40%) (Bliss et al. 1966). In land crabs and *Birgus latro*, dehydration and changes in hemolymph concentration are resisted using combinations of both behavioral (immersion, burrowing, water storage in the body or branchial chambers, and drinking) and morphophysiological (evolutionary reduction in gill size, urine reprocessing, excretion of nitrogenous waste as urea or uric acid) adaptations (Greenaway 1988; Greenaway et al. 1988; Wolcott 1991).

Excretion

The majority of terrestrial crustaceans, like their aquatic ancestors, are ammonotelic, excreting ammonia as the main waste product (Dresel and Moyle 1950; Linton et al. 2017). Only one species, *Birgus latro* is known to be primarily purinotelic, producing white fecal pellets of guanine and uric acid (Greenaway and Morris 1989; Linton et al. 2005, 2017). Even completely air-breathing gecarcinid crabs with well-developed lung-like structures, still require periodic immersion in water to facilitate nitrogen excretion (Adamczewska and Morris 1996; Dela-Cruz and Morris 1997a, 1997b). Ammonia is eliminated either in solution (excretory fluid) or as a gas in woodlice and talitroids (O'Donnell and Wright 1995; Linton et al. 2017). Waste nitrogen is stored as transaminated amino acids such as glutamate, glutamine, and glycine, between excretory bouts (Linton et al. 2017). Terrestrial isopods, amphipods, and decapods have solid purine urate deposits synthesized from excess dietary nitrogen, which are stored inside the connective tissue (Linton and Greenaway 1997, 1998; Linton et al. 2017). It has been suggested that these deposits function as either excreta or temporary nitrogen storage and are generally not used during times of negative nitrogen balance or in situations of high nitrogen demand (oogenesis and molt) (Linton and Greenaway 1997). In woodlice, urates seem to function as a cation store during dehydration or as an antioxidant to prevent oxidative tissue damage (Linton et al. 2017).

Physiology of breeding

For most terrestrial macrocrustaceans, reproductive biology and reproduction cycles are generally similar to their aquatic relatives, although a decrease in

the number of eggs in parallel with an increase in the egg size (sometimes only one large egg) and reduced (abbreviated) development occurs in some species (Williamson 1951; Steele and Steele 1975; Wildish 1979; Cardoso et al. 2001). Terrestrial crustaceans are mostly iteroparous, while some woodlice are known to be semelparous (Warburg et al. 1993; Linsenmair 2008). All terrestrial macrocrustaceans have internal fertilization, effectively conserving sperm in the female genital tract (e.g., Longo et al. 2011). Talitroids and woodlice have direct development inside an external pouch formed by the brood plates (oostegites) (Richardson et al 2001a, b), without an aquatic larval stage, which is a crucial adaptation for a fully terrestrial lifestyle. The larval development of decapods depends on their origin. Taxa derived from the marine environment still have to release larvae into the sea, returning to the mainland as the last zoeal/megalopa stages, while taxa of freshwater origin mostly have reduced or abbreviated development and can live in terrestrial habitats far from the sea coastline (Bliss 1979; Wolcott 1988). Most terrestrial ostracods are described from asexual populations (Pinto et al. 2005a, 2005b), especially in Darwinulidae, whose lineage was asexual for at least 200 Mya (Martens et al. 2003; Pinto et al. 2004, 2005a, 2005b). Parthenogenesis seems to be a favorable pre-adaptation, since most known terrestrial ostracods exhibit very low densities (with some exceptions, such as Brazilian *Penthesilenula*) and are unable to move over long distances (Pinto et al. 2004, 2005b). Terrestriality of some ostracods may involve the protection of fertilized eggs from desiccation. Developing embryos of the moss-dweller *Scottia audax* can be preserved in the maternal shell until they become free-living juveniles (Chapman 1961; Glime 2017a).

Low metabolism and longevity

Slow growth and longevity increase the time available for the accumulation of dietary nitrogen and other nutrients required for the growth of animals. For example, the minimum intermolt nitrogen requirement of *Gecarcoidea natalis* is only 4.8±1.7 mmol N/kg dry body weigh/day due to a low rate of basal protein catabolism (0.12±0.04% total body protein/day) and low fecal nitrogen concentration (38–56 mmol N/kg of dry weight) (Linton and Greenaway 2000). This way, *G. natalis* can cover the nitrogen requirements of intermolt, molt, and oogenesis from its nitrogen-poor leaf litter diet (Linton and Greenaway 2000, 2007). Mass-specific metabolic rates of animals and thus basal protein catabolism and minimum nitrogen requirements decrease with increasing body size. Life spans for many terrestrial herbivorous crabs are long with estimates of 20+ years for *G. natalis* (Green 2004) and *Cardisoma guanhumi* (Wolcott 1988), 12+ years for *Coenobita clypeatus* (Chace 1972), and 8–17 years for *Ucides cordatus* (Pinheiro et al. 2005). Longevity is seemingly linked to large body size in the gecarcinids. The lifespan of *Birgus latro* is estimated as 40–60 years (Greenaway 2003). Sexual maturity in large land crabs is not attained until 3–4 years of age (Henning 1975; Wolcott 1988; Green 2004; Pinheiro et al. 2005).

Other physiological adaptations

Terrestrial microcrustaceans are fragmentarily studied for any physiological adaptations, although the absence of hemoglobin is considered an adaptation

for a bryophytic lifestyle in harpacticoids. This suggests that oxygen is present in sufficient amounts and energy-requiring development of the pigment is not necessary (Green 1959; Glime 2017a, b). Land crab *Ocypode quadrata* can maintain its body temperature lower than the ambient air temperature using its enlarged claws and evaporation from the surface of the exoskeleton (Weinstein and Full 1994; Weinstein et al. 1994). Semi-terrestrial crabs of the genus *Uca* also use their enlarged claw for heat transfer to or from the environment (Windsor et al. 2005). Some woodlice evolved specific chemical (gland secretions and accumulation of potentially toxic concentrations of metals in their body tissues), morphological (heavily incrusted armor), and behavioral defenses (rolling into a ball or clinging to the substrate) as protection from specialized predators (Sutton 1972; Deslippe et al. 1996; Schmalfuss 1984).

Specific behavioral adaptations

Regulation of temperature and humidity

Shore woodlouse *Ligia italica*, living on and under rocks along the Mediterranean coasts, is strongly photonegative at temperatures of 20–30 °C, somewhat less at 6–10 °C, and photopositive at 40 °C when forced to leave rock crevices to find a cooler environment (Perttunen 1961). Desert-dwelling woodlice can maintain their heat and water exchange within their physiological tolerance limits by nocturnal activity and the ability to roll up into an almost perfect sphere thus preventing moisture loss (Linsenmair 1985, 1987, 2008; Shachak 1980; Shachak and Newton 1985). Conglobation is considered a mechanism preventing evaporation since the water loss rate is decreased significantly (up to 35%) by this behavior, depending on relative humidity (Smigel and Gibbs 2008).

Gecarcinidae land crabs are diurnal and nocturnal, but their activity is always positively correlated with relative humidity (Green 1997), and increases during the wet season, when humidity, and also the availability of seeds and seedlings are higher (Capistrán-Barradas et al. 2003; Sherman 2003; Lindquist and Carroll 2004). With the risk of desiccation, the activity of land crabs decreases when the humidity falls below 88% and stops below 77% (Green 1997; Hicks 1985). The surface soil temperatures (compared to air temperature) have a significant negative impact on the crab activity and abundance (Govender et al. 2008). Many land crabs spend the daytime inside their burrows, avoiding high surface temperatures (Atkinson and Taylor 1988). For example, at an air temperature of 35 °C and surface soil temperature of ~ 48–50 °C, the temperature inside burrows of land crab *Gecarcinus lateralis* at 40 cm depth ranged within 28–32 °C, providing sufficient protection from high temperatures and low humidity (Bliss 1968; McMahon and Burggren 1988; Govender et al. 2008). The burrowing in the humid soil allows some species to survive with little or no access to free-standing water (Greenaway and MacMillen 1978; Greenaway 1994). However, high ground water levels often preclude deep burrowing, which reduces the habitat of some forest crab species (Govender et al. 2008). Aestivation (summer sleep) is known for desert woodlice (Edney 1964) and terrestrial crabs (MacMillen and Greenaway 1978; Storey and Storey 2012). Desert-dwelling crabs able to aestivate can remain inside their clay-plugged burrows for up to 6 years, waiting for the rain (Ng et al. 2008).

Some desert woodlice have developed social behavior, diurnal activity, and semelparous reproductive strategy (Linsenmair 1974, 1985, 1987, 2008; Caubet et al. 2008; Hornung 2011). The advantage of semelparous reproduction in this case is apparently to invest all the accumulated resources in one reproductive effort since the chances of finding suitable conditions in the deserts are small. Aggregation is also considered one of the adaptive mechanisms against desiccation (Devigne et al. 2011; Broly et al. 2012, 2013b, 2014) and may create a local humid microclimate for all individuals in a small volume (Schliebe 1988). Additionally, aggregation stimulates reproduction in females, accelerating their vitellogenesis (Caubet et al. 1998) and growth (Takeda 1980), which is probably controlled by specific pheromones (Kuenen and Nooteboom 1963; Takeda 1980).

Feeding activity

Saprophagous or herbivorous crustaceans tend to select food items of higher quality that contain substantial amounts of easily digestible lipids, carbohydrates, and proteins. For instance, *B. latro* consumes mainly fruits, seeds, and animal material, and practices a highly selective feeding strategy using sophisticated olfactory sense (Fletcher et al. 1990; Hicks et al. 1990; Greenaway 2001). The South African woodlouse *Alloniscus marinus* exhibits unusual arboreal feeding behavior by eating the green leaves of the bietou bush *Chrysanthemoides monilifera*, but not the forest litter (Glazier and Kleynhans 2015). Some crabs feed by rasping leaf tissue from the upper or lower surface of the leaves (Cannicci et al. 1996; Erickson et al. 2003). This can enhance the quality of ingested material by increasing the ratio of mesophyll tissue to indigestible lignin and cutin compared with ingestion of whole leaf material. Intraspecific competition between *Cardisoma guanhumi* in Florida is such that crabs rush from their burrows to compete for falling leaves (Herreid 1963). Gecarcinid crabs also store leaves in their burrows where fungi and bacteria rapidly colonize them, but there is no quantitative data on the rate of utilization of the processed litter (Herreid 1963; O'Dowd and Lake 1989; Green et al. 1999). Predation and cannibalism in *Gecarcinus lateralis* increase when animals are maintained on a low-nitrogen diet (Wolcott and Wolcott 1984, 1987, 1988). Ambush predation is known for terrestrial crayfish (Graham et al. 2022). Such feeding behavioral adaptations are likely to be widespread in terrestrial crustaceans but remain poorly studied.

Parental care

Females of some woodlice provide maternal care to eggs and young, supplying nutrients and providing mancae (early-instar juveniles) with an aqueous environment in the modified marsupium (Warburg 1987; Warburg and Rosenberg 1996), which is unique among terrestrial arthropods (Surbida and Wright 2001; Kight and Nevo 2004; Lardies et al. 2004). Marsupium of some terrestrial woodlice contains lipid globules in cotyledons that secrete the marsupial fluid and supply juveniles with nutrients (Hoese and Janssen 1989; Csonka et al. 2015). Maternal care in talitroids includes controlling the osmotic environment of the pouch, cleaning eggs, and perhaps feeding young in a brood pouch (Morritt and Richardson 1998; Richardson et al 2001a, b). Jamaican snail crab

Sesarma jarvisi breeds inside water-filled shells of the land snail of the genus *Pleurodonte* and provides parental care for larvae (Diesel and Horst 1995; Diesel and Schubart 2000). Vampire crab *Geosesarma notophorum* and some other species of the genus from high-altitude forests of Sumatra exhibit a completely abbreviated development and unusual brooding behavior in which the female carries her offspring on the dorsal surface of the carapace for approximately 2–3 days after hatching (Ng and Tan 1995; Ng et al. 2015b; Ng and Ng 2019). The most interesting case of parental care is described in the Jamaican crab *Metopaulias depressus*, which includes the long-term maintenance of optimal levels of appropriate conditions (oxygen, pH, and calcium (Ca+)) for larval development (Diesel 1989; Diesel and Schuh 1993). These eusocial crabs live in large colonies consisting of the mother and her offspring, where the older offspring participate in the colony defense, and young adult females remain in their natal colony as subordinate (non-reproductive) females, with the prospect of inheriting their mother bromeliad as a breeding site (Diesel and Schubart 2000, 2007; Vogt 2012).

Breeding migrations

One of the most important features and adaptations of land gecarcinid crabs is the annual migration to the coast to release their eggs into the ocean (Adamczewska and Morris 1996, 2001; Morris 2005; López-Victoria and Werding 2008), with the most exciting migrations of breeding females known for *Gecarcinus ruricola* in Providence Island (Hartnoll and Clark 2006), *Gecarcoidea natalis* in Christmas Island (Hicks 1985; Hicks et al. 1990) and *Gecarcinus lateralis* in Florida and Bermuda (Bliss et al. 1978). During these migrations, crabs can travel up to 5 km daily for many days to reach the coastline and must maintain moving for extended periods, up to 12 h each day (Hicks 1985; Adamczewska 1997; Green 1997). In land crabs from arid or semi-arid habitats, young individuals grow very quickly after hatching, and then return to the ground and build their burrows at the beginning of the dry season (McCann 1938). Very high fertility in land crabs, compared to any of soil inhabitants, for example, 19,000–109,000 eggs in *Gecarcinus lateralis*, determines the high reproductive potential that ensures the prosperity of crabs in terrestrial habitats (Green et al. 1997).

Behavioral adaptations are likely to predominate over morphological and physiological ones, including, for example, avoiding harsh conditions, social and specific breeding behavior with migrations to water, and other behavioral patterns. The main strategies in the hot and dry climate include minimizing water evaporation by seeking shelter and having a nocturnal lifestyle. At the same time, most of the morphological, physiological, and behavioral adaptations presented above suggest that terrestrial crustaceans are evolving and adapting to terrestrial habitats, but still have a range of strong limitations hampering their wider distribution and dominance in terrestrial ecosystems.

Additional literature on the topic

Most studied are adaptations of woodlice for their terrestrial lifestyle such as reduction in size (Hornung 2011), specific sensitive structures (Hornung 2011), cuticle structure (Bursell 1955; Schmalfuss 1978; Holdich 1984), surface

structures (Holdich and Lincoln 1974; Holdich 1984), pleodopodal lungs (Cloudsley-Thompson 1988; Schmidt and Wägele 2001; Paoli et al 2002; Wright and Ting 2006) and brood pouch structure (Hoese 1984). Numerous reviews treat various aspects of arthropod terrestrialization, including locomotion (Weihmann 2020) and other behavioral adaptations (Warburg 1968; Powers and Bliss 1983; Lagerspetz and Vainio 2007), chemoreception and thermoreception (Ache 1982), general physiology (Carefoot 1993; Greenaway 1999), the evolution of the olfactory system (Krieger et al. 2015, 2021), respiration (McMahon and Burggren 1988; Morris 2002), nitrogenous waste metabolism (Morris 2002; Linton et al 2017), water and hemolymph conducting system (Horiguchi et al. 2007), nutrition (Zimmer and Topp 1998b; Zimmer 2002a), diseases (Provenzano 1983; Federici 1984), and specific adaptation to the arid environment (Cloudsley-Thompson 1975).

General review of adaptations of Crustacea to land are presented in Edney (1968), Bousfield (1968), Bliss and Mantel (1968), Cloudsley-Thompson (1988), Morritt and Spicer 1998; Dunlop et al. (2013), Richardson and Araujo (2015), Glime (2017a,b), and Sfenthourakis et al. (2020).

Trophic interactions and role in the ecosystems

The feeding activity of macroinvertebrates is considered one of the most important initial processes of the decomposition of organic matter (Ott et al. 2012; Griffiths et al. 2021; Potapov et al. 2022). Terrestrial macrocrustaceans, along with other macroarthropods (millipedes, termites) and earthworms, can be cumulatively classified as primary decomposers and as ecosystem engineers that substantially modify the physical structure of plant litter and soil (Jones et al. 1994; Lawton and Jones 1995; Lavelle et al. 1997).

Litter consumption and decomposition

Terrestrial decapods living in coastal forests forage primarily on plant material such as leaf litter (Kellman and Delfosse 1993; Sherman 2003), fruits (Capistrán-Barradas and Moreno-Casasola 2006), seeds (Garcia-Franco et al. 1991; Lindquist and Carroll 2004) and seedlings (Green et al. 1997; Sherman 2002). The huge densities of land decapods (crabs and hermit crabs) on oceanic islands lead to the removal of a significant amount of litterfall and changes in the structure of the nutrient cycles (O'Dowd and Lake 1989; Kellman and Delfosse 1993). Decapods sometimes monopolize litter recycling (Green et al. 1997). For instance, the Bermuda blackback land crab *Gecarcinus lateralis* may consume 75–97% of the leaf litter biomass available for decomposition (Kellman and Delfosse 1993); the land crab *Gecarcoidea natalis* processes 39–87% of annual litterfall on Christmas Island (Green et al. 1999).

Smaller terrestrial macrocrustaceans, such as talitroids (Friend 1975; O'Hanlon and Bolger 1999; Handa et al. 2014) and woodlice (Hassall and Sutton 1978; Hassall et al. 1987; Mocquard et al. 1988; Špaldoňová and Frouz 2014) are also highly efficient detritivores. They can consume 6–55% of the total litterfall, playing an important role in litter decomposition and nutrient mineralization. Fully terrestrial woodlice may compete with other saprophagous soil animals for high-quality food resources (Rushton and Hassall 1983), whereas competition

between sympatric species may be reduced by species-specific nutritional requirements and digestive capabilities (Zimmer et al. 2002).

Crustaceans enhance litter decomposition both directly, via consumption and assimilation and indirectly by fragmenting and increasing the surface area available for colonization by saprotrophic microbiota and stimulating microbial activity in their feces (Coughtrey et al. 1980; Teuben and Roelofsma 1990). As could be expected, woodlice are best studied in this respect. Leaf litter eaten and digested by isopods differs physically and chemically from intact leaves (Hassall et al. 1987; Gunnarsson et al. 1988). Increased microbial activity in the gut and fresh feces (Zimmer 2002a, 2002b; Zimmer et al. 2002, 2003) ensures the degradation of cellulose (Hartenstein 1964; Zimmer and Topp 1998b; Zimmer and Brune 2005) and even phenolic leaf litter compounds (Neuhauser and Hartenstein 1976; Zimmer and Topp 1998a; Zimmer 1999). Passing through the digestive canal, saprotrophic microflora changes both in density and in species composition (Hartenstein 1964, 1982; Coughtrey et al. 1980; Ineson and Anderson 1985). Recent studies of gut microbiota in the woodlice *Armadillidium vulgare* and *Porcellionides pruinosus* revealed a very diverse bacterial community that varies between host populations, suggesting an important proportion of environmental microbes in the gut-associated microbiota (Bouchon et al. 2016; Delhoumi et al. 2020). Microbial inoculation of leaf litter increased litter palatability (Hartenstein 1964; Hassall et al. 1987; Rushton and Hassall 1983) and quality (Ullrich et al. 1991; Uesbeck and Topp 1995; Zimmer and Topp 1997, 2000) by reducing the C/N ratio and/or quantity of phenolic compounds (Kuiters and Sarink 1986; Poinsot-Balaguer et al. 1993; Zimmer 1999, 2002a). Noteworthy, woodlice cannot separate low- and high-quality litter (i.e., oak vs. alder) immediately after leaves had been shed, but can do so after early stages of microbial decomposition, since the microbiota or their waste seem to indicate high-quality food (Zimmer et al. 2003).

The consumption and bioturbation of leaf litter affect the chemical composition and rate of oxygen saturation of the soil, accelerate the decomposition processes, and stimulate the activity of fungi and bacteria (Richardson and Morton 1986; Griffiths et al. 1989; van Wensem 1989; Teuben and Roelofsma 1990; Kautz et al. 2000). Talitroids can reduce the rate of leaching of cations, possibly because cations are bound in the compact fecal pellets produced by landhoppers (Richardson and Morton 1986). An increase in ATP turnover in the *Spartina* litter grazed by the landhopper *Orchestia grillus* leads to an increase in nitrogen reserves, which is important for the long-term health of the coastal forests (Lopez et al. 1977).

Bioturbation

The burrowing activity of terrestrial crustaceans is one of their main ecological functions. Smaller species have less of an effect, although the burrowing activity of woodlice of the genus *Hemilepistus* appears to be an important factor in soil formation in arid regions (Kozlovskaya and Striganova 1977). Forest crabs and crayfish can significantly affect forest ecosystems by increasing soil aeration through burrow construction (Richardson 1983; Green 2004; Pérez-Chi 2005; Gutiérrez et al. 2006), as well as removing the leaf litter and causing local nutrient enrichment of the soil by gathering leaves around or inside their burrows (O'Dowd and Lake 1989; Sherman 2003, 2006). Crayfish

Creaserinus gordoni annually moved over 80 metric tons of soil ha/yr and created 29–49 km/ha of subterranean tunnels (Welch et al. 2008). Burrows of *Procambarus hagenianus* may extend 4 m below the surface (Fitzpatrick 1975), and in suitable habitats, there may be at least one crayfish burrow system per square meter (Reynolds et al. 2013). The activity of the East African land crabs *Neosarmantium meinerti* and *Cardisoma carnifex* is limited to the upper 20 cm of soil, where it affects ~ 0.07% of the soil daily or about 25% per year (Micheli et al. 1991). In another study, combining estimates of burrow volume, density, and turnover suggest that red crabs *Gecarcoidea natalis* can increase the surface area of soil available for gas exchange by ~ 13%, although for one year they probably turn over < 1% of the top 20 cm of the forest soil in Murray Hill, Christmas Island (Green 1997). The physical removal of litter from the surface to deeper and moister soil layers may be one of the most important indirect contributions to decomposition processes (Hassall et al. 1987). The litter mass was 5.0–5.6 times higher in crab exclosures than in control open plots (Kellman and Delfosse 1993; Sherman 2003). Leaf litter caching inside the burrows is common in gecarcinid land crabs (Fimpel 1975; Henning 1975; O'Dowd and Lake 1989), but the accumulation of leaf litter around the entrance is described only in *Gecarcoidea natalis* (O'Dowd and Lake 1989; Green 2004). Burrows of large land crabs such as *Cardisoma guanhumi* are durable and turn over very slowly (Herreid and Gifford 1963; Green 2004). Fairly long-lived burrows, with an average turnover time of more than 4 years create a mosaic of nutrient hotspots potentially useful for seedling growth (O'Dowd and Lake 1989; Green 2004). They can also have a significant effect on carbon sequestration, and since the soil is enriched with nutrients, the density of plant roots is higher around burrowing microsites in mainland forests (Sherman 2006). Other burrowing terrestrial crustaceans, such as crayfish, perform similar ecological functions (Kingwill 2008; Loughman 2010; Bryant et al. 2012). These data suggest that forest crabs and crayfish may have a somewhat different effect on aboveground processes compared to crabs in tidal habitats, which constantly dig numerous small burrows (Bertness and Miller 1984; Smith et al. 1991), thus constantly aerating the substrate, and sometimes even draining swampy hypoxic soils (Katz 1980; Montague 1980, 1982; Takeda and Kurihara 1987).

Plant recruitment

Woodlice *Armadillidium vulgare* and some other species are partly granivorous, in some habitats being efficient predators of seed of *Taraxacum*, *Capsella*, *Poa*, and other plants (Saska 2008; Honek et al. 2009; Singer et al. 2012). *Australiodillo bifrons* and *Porcellio scaber* feed on wheat seedlings under laboratory conditions and probably can cause significant damage to wheat seedlings when reaching very high densities in the field (Paoletti et al. 2008). The activity of land hermit crabs and forest crabs may be a major factor controlling plant communities through feeding on seeds and seedlings, recycling nutrients, and affecting tree density and size structure (Louda and Zedler 1985; O'Dowd and Lake 1991; Green et al. 1999; Lindquist et al. 2009). Land crabs greatly affect seedling recruitment in semi-deciduous seasonal dry tropical forests (Delfosse 1990; Kellman and Delfosse 1993). For example, land crabs *Gecarcoidea natalis* grazed 25 seedling species on Christmas Island, processing more than

80% and eating ~ 47% of them (Green et al. 1997). Seedling density was 20-fold higher, and seedling richness was 5-fold higher in crab exclosures than in unfenced control plots (O'Dowd and Lake 1990; Green et al. 1997). In mainland tropical forests, seedling density increased by 144% in crab exclosures (Sherman 2002). Annual fluctuations in the density of the crab population may allow pulses of tree recruitment in "low crab" years (Green et al. 1997, 2008; Sherman 2002; Lindquist and Carroll 2004). Indirectly, the removal of leaf litter by crabs can change the visibility of seeds to predators, as well as the micro-environmental conditions for seed germination and seedling establishment (Kellman and Delfosse 1993). Leaf litter depth and tree seedling density are negatively correlated with the burrow density of land crabs *Gecarcinus quadratus* in Costa Rica (Griffiths et al. 2007). Land crabs differentially prey on seeds and seedlings along nutrient, chemical, and physical environmental gradients, and crab consumption has primacy over many environmental factors, acting as the main limiting factor of tropical tree recruitment, and affecting the structural and compositional organization of coastal forests (Green et al. 1997).

Predators

Terrestrial microcrustaceans are involved in complex trophic relationships, although to date they have been studied fragmentary. The cosmopolitan soil harpacticoids *Phyllognathopus viguieri* actively prey on different species of soil nematodes using their modified leaf-like maxillipeds (Lehman and Reid 1993). Adults and copepodites of *Virbiocyclops silvaticus* occasionally consumed nematodes and injured oligochaetes (Rocha and Bjornberg 1988). Soil harpacticoid *Epactophanes* sp. are classified among bacterial-feeding organisms but may also feed on nematodes (Birch and Clark 1953; Reid 2001).

Woodlice can prey on smaller animals, e.g., insect larvae. For example, *Armadillidium vulgare* were observed feeding on pupae of fruit flies *Drosophila melanogaster* in citrus orchards in California, although alternative food was abundant (Edney et al. 1974). Large coconut crab *B. latro* can prey on other land crabs (Krieger et al. 2016), birds, and rats (Kessler 2005; Laidre 2017). The land crab *Gecarcinus lateralis* is a significant predator of the abundant Bahamian land snails of the genus *Cerion* (Quensen III and Woodruff 1997), crab *Rodriguezus garmani* was observed to consume snakes (Maitland 2003), large land crabs are major predators of nesting sea birds (Paulay and Starmer 2011). Land hermit crabs (*Coenobita* spp.) and large gecarcinid crabs have been reported to feed on an extremely wide dietary spectrum, including dead animals washed into the tidal zone and their feces (Burggren and McMahon 1988; Dunham and Gilchrist 1988; Thacker 1996). High abundance, along with the ability to dispose of all organic residues on the coast and in the surrounding forest in a very short time (Hsu et al. 2018) suggests the importance of crabs as consumers of carrions (Degener and Gillaspy 1955; Niering 1956, 1963; Wiens 1962; Page and Willason 1983). For instance, *Coenobita* spp. potentially control fly populations by rapid removal of carrions. In areas where hermit crabs were common, the flies were seemingly less numerous than in areas where hermit crabs were absent (Page and Willason 1982, 1983). Small *Geosesarma malayanum* and *Geosesarma peraccae* crabs climb into the pitchers of *Nepenthes ampullaria* and eat the prey, but sometimes they fall into the trap and die (Ng and Lim 1987; Ng 1988).

Prey

Knowledge of the position of microcrustaceans in terrestrial food webs is extremely limited. In wet habitats, they are likely consumed by predators along with other microarthropods. For example, terrestrial harpacticoids are among the main prey items of arboreal wandering salamanders *Aneides vagrans* living in wet bryophytes more than 80 meters above the forest floor in the Californian redwood forest in the USA (Camann et al. 2011). Larger crustaceans are readily consumed by a wide array of vertebrate and invertebrate predators. Generalist predators rarely feed on woodlice (Gorvett 1956), but such cases are known for hedgehogs (Shilova-Krassova 1952), shrews (Perneta 1976), moles (Godfrey and Crowcroft 1960), frogs, toads, lizards, birds, and some predatory arthropods (Sunderland and Sutton 1980; Bureš and Weidinger 2003). On the other hand, ants of the tropical genus *Leptogenys* (Dejean 1997; Dejean and Evraerts 1997), spiders of the Palaearctic genus *Dysdera* (Pollard et al. 1995; Rezáč and Pekár 2007; Pekár and Toft 2015) and toad bugs *Nerthra macrothorax* possess adaptation for the effective capture of armored woodlice and detoxication mechanisms alleviating feeding on woodlice (Sunderland and Sutton 1980; Pekár et al. 2016). Approximately 15 other spider species from ten families are suggested to be specialized woodlice predators (Bristowe 1941, 1958; Uhlenhaut 2001; Rezáč et al. 2008). The desert scorpion *Scorpio maurus* is the main predator of *Hemilepistus reaumurii*, which may comprise 70% of the scorpion's diet (Dubinsky et al. 1979; Ward 2009). The nocturnal lifestyle of forest talitroids is sometimes explained by the minimization of dehydration as well as predation by birds (Friend and Richardson 1986).

Raccoons, coatis, mongooses, cats, foxes, herons, and other migrating and local birds feed on land crabs in mainland habitats (Sherman 2002; Lindquist and Carroll 2004). In places where there are no large predatory mammals or birds, land crabs may be released from the predator pressure, although the coconut crab *B. latro* hunts on land crabs on tropical islands (Alexander 1979; Hicks et al. 1990; Pérez-Chi 2005). The invasive yellow crazy ant *Anoplolepis gracilipes* have significantly affected the population of the red land crab *Gecarcoidea natalis* on Christmas Island (O'Dowd et al. 2003; Green et al. 2004; Abbott 2005). This had a cascading effect on native species populations at several trophic levels (O'Dowd et al. 2003). Invasive predatory nemertean *Geonemertes pelaensis* significantly declined populations of terrestrial crustaceans on some Japanese islands (Shinobe et al. 2017). The potential for invasion meltdown following the local extinction of crab populations suggests that land crabs are a keystone species in the tropical forests of oceanic islands (O'Dowd et al. 2003).

Coconut crabs and crabs of the genera *Cardisoma* and *Ucides* are a widely recognized food source for humans (Carpenter and Niem 1998; Alves et al. 2005; Firmo et al. 2012; Maynard and Oxenford 2014) and have ethno-medicinal significance (for example, Rana 2018), which is a rare case for saprophagous invertebrates from terrestrial ecosystems.

Antipredatory strategies among terrestrial crustaceans are very diverse and include tonic immobility, aggregation or sticking to the ground, the release of strongly acidic secretions, jumping, and effective escape (see review in Tuf and Ďurajková 2022). In addition, they can team up with other individuals, and use

stridulation (Cividini et al 2020). Some species developed prickly tergites and aposematic coloration or posture. Most of these strategies have not yet been studied in detail.

Parasites and macrosymbionts

Many internal parasites of terrestrial crustaceans are similar to those of their aquatic relatives. There are however specifically terrestrial parasites, such as ~ 150 species of widely distributed Rhinophoridae flies (Insecta: Diptera) known as specialized parasitoids of woodlice (Pape and Arnaud 2001; Nihei 2016; Wood et al. 2018). Two Caribbean flies, *Drosophila carcinophila* and *Drosophila endobranchia*, live exclusively on gecarcinoid land crabs, while the Christmas Island fly, *Lissocephala poweilli*, lives on both crabs and hermit crabs, including *B. latro*, completing their larval development on or inside their crustacean hosts (Stensmyr et al. 2008). Parasitic relationships between an unidentified species of Sphaeroceridae (Diptera) and the land crab *Cardisoma crassum* are known from Cocos Island, Costa Rica (Gymez 1977). Specialized Cancrincolidae copepods (Copepoda, Harpacticoida) are associated with large land crabs, living inside their branchial chambers (Huys et al. 2009).

Numerous mermithid nematodes, rotifers, rickettsia and other bacteria, and viruses are known from woodlice and land crabs (Provenzano 1983; Federici 1984; Rigaud and Moreau 2004; Wang 2011; Ugbomeh and Bajor 2015). In particular, common iridoviruses (Iridoviridae) confer an iridescent blue color to the body of the infected woodlice (Williams 2008).

Burrows of land crabs and crayfish provide habitat for obligatory and facultative arthropod symbionts (e.g., Bright and Hogue 1972; Horwitz and Knott 1991), including various flies and mosquitoes (Carson and Wheeler 1973; Carson 1974; Gómez 1977; Bertrand 1979; Goettel et al. 1981). *Gramastacus insolitus*, a very small non-burrowing Australian freshwater crayfish, survives droughts in the burrows of larger burrowing crayfish *Geocharax falcata* and *Cherax destructor* (Johnston and Robson 2009). Mosquitoes of the genus *Deinocerites* use the upper portions of burrows of large forest crab *Cardisoma guanhumi* as daytime resting sites, while their larvae develop in the water that accumulates at the bottom (Downes 1966; Adames 1971; Wolcott and Wolcott 1990). In turn, killifish *Rivulus marmoratus* feed on larvae of *Deinocerites* inside the burrows (Taylor 1990). Several woodlice taxa are associated with the nests of social insects, ants, and termites, showing specific morphological (reduction/absence of eyes and body pigmentation) and behavioral (evasive movements) adaptations tolerated by the hosts (Ferrara et al. 1988; Taiti and Ferrara 1988; Kronauer and Pierce 2011; Parmentier et al. 2017; Taiti 2018). Massasauga rattlesnakes (*Sistrurus catenatus*) commonly choose burrows of cambarid crayfish in southeastern Canada as a hibernation site during the winter (Maple 1968; Seigel 1986; Kingsbury 1996, 1999). Subterranean flowers of *Aspidistra elatior* are allegedly pollinated by collembolans and landhoppers *Platorchestia japonica* (Kato 1995; Conran and Bradbury 2007), although recent studies suggest that pollination is performed by fungus gnats (i.e., *Cordyla sixi* and *Bradysia* sp.) rather than crustaceans (Suetsugu and Sueyoshi 2018).

Migrations and energy flows

Among the most prominent and significant ecological functions of terrestrial decapods are migrations, one of the most famous and well-studied examples of the invertebrate-mediated transport of organic matter and nutrients from marine to terrestrial ecosystems and back (Klaassen 1975; Wolcott 1988; Hicks et al. 1990; López-Victoria and Werding 2008; Lindquist et al. 2009). Less studied connections can represent ecologically significant lateral links between terrestrial and freshwater ecosystems. Semi-terrestrial gecarcinucid crabs from Asian streams are saprophages (Ng 1989; Lim 2013; Ng and Yeo 2013) feeding on coarse organic matter from neighboring land, e.g., leaf litter, often being the main macrodecomposer (Hill and O'Keeffe 1992; Abdallah et al. 2004; Dobson et al. 2007). They are also opportunistic predators that feed on smaller aquatic organisms (Abdallah et al. 2004; Dobson 2004), being in turn a food source for larger terrestrial animals (Ng 1989), thus carrying out the energy transfer between river and forest ecosystems.

Methods used for sampling of terrestrial crustaceans

Methods of collecting terrestrial macrocrustaceans (mainly woodlice and landhoppers) do not differ significantly from those designed for collecting soil macrofauna, such as Macfadyen extractors (Macfadyen 1961), pitfall trapping, or hand-sorting of soil samples. Other methods that are occasionally used include 'cryptozoa boards', i.e., artificial shelters placed on the soil surface (e.g., Hodge and Standen 2006). In contrast, sampling microcrustaceans requires specifically designed approaches. Insufficient knowledge of the diversity and ecology of microcrustaceans is clearly related to the lack of adequate and well-known methods for qualitative and especially quantitative sampling of these animals. Small crustaceans can be extracted by flotation or hand-sorting of alcohol-fixed material under the dissecting microscope (e.g., Bernier and Gillet 2012), but these methods are rarely used. Common "dry" extractors (Berlese or Tullgren funnels) used to collect microarthropods are not suitable because microcrustaceans are essentially aquatic animals. "Wet" extractors (Baermann funnels) are designed mainly for nematodes and enchytraeids having thin and smooth bodies and are likely ineffective for quantitative sampling of soil microcrustaceans.

The qualitative methods for collecting terrestrial crustaceans listed below are borrowed mainly from sampling methodologies targeting meiofauna, underground (subterranean) and hypogean microcrustaceans, and collecting burrowing crustaceans such as crabs and crayfish. Many quantitative methods designed for marine and freshwater benthic animals are probably also applicable to quantitative sampling of terrestrial crustaceans (e.g., Boxshall et al. 2016; Hughes and Ahyong 2016). A detailed account of the common extraction techniques of small crustaceans from the ground is given in Pfannkuche and Thiel (1988) and Boxshall et al. (2016). The technique of the wet sieving adapted for the sampling of soil- and leaf litter-dwelling copepods and other small crustaceans is presented in Kikuchi (1984) and Fiers and Ghenne (2000). Generally, a portion of the soil or leaf litter is placed in a beaker or bucket with water and agitated, and the supernatant is decanted into a stack of sieves, with the coarsest sieve at the top to remove larger pieces of detritus. The target size fraction is retained on the finest sieve and subsequently inspected using a light micro-

scope. Sampling from waterlogged soils can be carried out by pumping and using a mesh for filtration (Hahn 2002; Leijs et al. 2009; Boxshall et al. 2016).

Research on and sampling of burrowing land crabs and crayfish are hampered by their nocturnal activity and underground lifestyle. Commonly used methods include burrow excavation (Ridge et al. 2008; Loughman 2010), opera house and drop nets (Bryant et al. 2012), pitfall traps (Shaw 1996), the Norrocky traps that capture crayfish at the entrance of the burrows (Norrocky 1984; Welch and Eversole 2006; Ridge et al. 2008), the burrowing crayfish net (Welch and Eversole 2006; Kingwill 2008; Ridge et al. 2008), and some others (see review in Bryant et al. 2012). Sometimes these methods are combined; a relatively recent emerging method involves the use of Alka-Seltzer/Aspirin tablets and soda water poured into the burrows with visible water or trialed in conjunction with flooding of burrows with water (Bryant et al. 2012).

Conclusions

Terrestrial crustaceans from six main lineages, representing ~ 4,900 currently known species, are widespread in terrestrial ecosystems. The diversity and ecology of terrestrial crustaceans have been studied to various degrees; in particular, the biology of microcrustaceans is still known fragmentarily. Woodlice, the most successful terrestrial crustaceans, have been able to adapt and colonize a wide range of diverse terrestrial habitats, including extreme ones. An array of morphological and physiological limitations (e.g., the absence of a waxy cuticle protecting against evaporation, and aquatic mode of reproduction), likely prevent most other lineages of crustaceans from competing with other terrestrial arthropods and achieving a wider distribution. Due to the high abundance and density in some terrestrial habitats, such as temperate and especially tropical coastal forests and islands, crustaceans often play important ecological roles, being ecosystem engineers and crucial components of food webs, including the upper trophic levels. In many other ecosystems, the diversity and ecological significance of terrestrial crustaceans, especially microcrustaceans, can be significantly underestimated. Although often neglected by soil ecologists, a full diversity of terrestrial crustaceans, besides isopods, should be regarded as a prominent component of soil communities.

Acknowledgements

Dr. Jacob D. Wickham (IPEE RAS) kindly improved the English of the manuscript.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

No funding was reported.

Author contributions

Both authors have made an equal contribution at all stages.

Author ORCIDs

Ivan N. Marin https://orcid.org/0000-0003-0552-8456
Alexei V. Tiunov https://orcid.org/0000-0003-2400-3559

Data availability

All of the data that support the findings of this study are available in the main text.

References

Abbott KL (2005) Supercolonies of the invasive yellow crazy ant, *Anteplolepis gracilipes*, on an oceanic island: Forager patterns, density and biomass. Insectes Sociaux 52(3): 266–273. https://doi.org/10.1007/s00040-005-0800-6

Abdallah A, De Mazancourt C, Elinge MM, Graw B, Grzesiuk M, Henson K, Kamoga M, Kolodziejska I, Kristersson M, Kuria A, Leonhartsberger P, Matemba RB, Meri M, Moss B, Minto C, Murfitt E, Musila SN, Ndayishinye J, Nuhu D, Oduro DJ, Provvedi S, Rasoma V, Ratsoavina F, Trevelyan R, Tumanye N, Ujoh VN, Van De Wiel G, Wagner T, Waylen K, Yonas M (2004) Comparative studies on the structure of an upland African stream ecosystem. Freshwater Forum 21: 27–47.

Abele LG (1970) Semi-terrestrial shrimp (*Merguia rhizophorae*). Nature 226(5246): 661–662. https://doi.org/10.1038/226661a0

Ache BW (1982) Chemoreception and thermoreception. In: Bliss DE (Ed.) The Biology of Crustacea (Vol. 3). Academic Press, New York, 369–398. https://doi.org/10.1016/B978-0-12-106403-7.50017-3

Adamczewska AM (1997) Respiratory eco-physiology and energetics of exercise and migration in the Christmas Island red crab *Gecarcoidea natalis* (Pocock, 1888) (Brachyura: Gecarcinidae). PhD thesis, University of Sydney, Sydney.

Adamczewska AM, Morris S (1996) The respiratory gas transport, acid–base state, ion and metabolite status of the Christmas Island Blue Crab, *Cardisoma hirtipes* (Dana) assessed in situ with respect to immersion. Physiological Zoology 69(1): 67–92. https://doi.org/10.1086/physzool.69.1.30164201

Adamczewska AM, Morris S (2001) Ecology and behavior of *Gecarcoidea natalis*, the Christmas Island red crab, during the annual breeding migration. The Biological Bulletin 200(3): 305–320. https://doi.org/10.2307/1543512

Adames AJ (1971) Mosquito Studies (Diptera, Culicidae). XXIV. A revision of the crab-hole mosquitoes of the genus *Deinocerites*. Contributions of the American Entomological Institute 7: 1–154.

Alcock A (1900) Materials for a carcinological fauna of India. No. 6. The Brachyura Catometopa or Grapsoidea. Journal of the Asiatic Society of Bengal, Calcutta 69(3): 279–486. https://doi.org/10.5962/bhl.title.15344

Alexander HGL (1979) A preliminary assessment of the role of the terrestrial decapod crustaceans in the Aldabran ecosystem. Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences 286: 241–246. https://doi.org/10.1098/rstb.1979.0031

Álvarez F, Winfield I, Cházaro S (2000) Population study of the landhopper *Talitroides topitotum* (Crustacea: Amphipoda: Talitridae) in central Mexico. Journal of Natural History 34(8): 1619–1624. https://doi.org/10.1080/00222930050117512

Alves R, Nishida AK, Hernández MIM (2005) Environmental perception of gatherers of the crab 'caranguejo-uçá' (*Ucides cordatus*, Decapoda, Brachyura) affecting their collection attitudes. Journal of Ethnobiology and Ethnomedicine 1(1): 1–10. https://doi.org/10.1186/1746-4269-1-10

Arias-Pineda JY, Tristancho JCQ (2017) First record of the invasive sandhopper, *Talitroides topitotum* (Burt, 1934) (Amphipoda: Talitridae) from Colombia. Boletín de la Sociedad Entomológica Aragonesa (S.E.A.) 61: 239–240.

Arnscheidt J, Hahn H-J, Fuchs A (2008) Aquatic subterranean Crustacea in Ireland: Results and new records from a pilot study. Cave and Karst Science 35(1): 53–58.

Arnscheidt J, Dooley J, Eriksson K, Hack C, Jürgen Hahn H, Higgins T, McCarthy TK, McInerney C, Wood P (2012) Biogeography and Ecology of Irish Groundwater Fauna: Assessment of the Distribution, Structure and Functioning of Subterranean Fauna within Irish Groundwater Systems. Strive Report. Environmental Protection Agency, Johnstown Castle, Ireland. https://www.epa.ie/pubs/reports/research/water/STRIVE_95_web.pdf [Accessed 3 April 2016]

Atkinson RJA, Taylor AC (1988) Physiological ecology of burrowing decapods. In: Fincham AA, Rainbow PS (Eds) Aspects of Decapod Crustacean Biology, Clarendon Press, Oxford, 201–226.

Battigelli JP, Berch SM, Marshall V (1992) Soil fauna communities in Cedar Hemlock and Hemlock–Amabilis fir forest types on northern Vancouver Island, B.C. Northwestern Environmental Journal 8: 213–214. https://doi.org/10.1139/x94-203

Battigelli JP, Berch SM, Marshall V (1994) Soil fauna communities in two distinct but adjacent forest types on northern Vancouver Island, British Columbia. Canadian Journal of Forest Research 24(8): 1557–1566. https://doi.org/10.1139/x94-203

Bennett CE (2008) A review of the Carboniferous colonisation of non–marine environments by ostracods. Senckenbergiana Lethaea 88(1): 37–46. https://doi.org/10.1007/BF03043976

Bernier N, Gillet F (2012) Structural relationships among vegetation, soil fauna and humus form in a subalpine forest ecosystem: A Hierarchical Multiple Factor Analysis (HMFA). Pedobiologia 55(6): 321–334. https://doi.org/10.1016/j.pedobi.2012.06.004

Bernot JP, Owen CL, Wolfe JM, Meland K, Jørgen Olesen J, Crandall KA (2022) Major revisions in pancrustacean phylogeny with recommendations for resolvingchallenging nodes. BioRxiv preprints. https://doi.org/10.1101/2022.11.17.514186

Beron P (1997) On the high mountain Isopoda Oniscidea in the Old World. Historia Naturalis Bulgarica 8: 85–100.

Beron P (2008) High Altitude Isopoda, Arachnida and Myriapoda in the Old World. Pensoft Publishers, Sofia, 556 pp.

Bertness MD, Miller T (1984) The distribution and dynamics of *Uca pugnax* (Smith) burrows in a New England salt marsh. Journal of Experimental Marine Biology and Ecology 83(3): 211–237. https://doi.org/10.1016/S0022-0981(84)80002-7

Bertrand J-Y (1979) Observations sur les crabes *Sudanonautes africanus* (Milne–Edwards 1869) et leurs terriers d'une savane de Lamto (Coted'Ivoire). Bulletin de la Société Zoologique de France 104: 27–36.

Biju Kumar A, Raj S, Ng PKL (2017) Description of a new genus and new species of a fully arboreal crab (Decapoda: Brachyura: Gecarcinucidae) from the Western Ghats, India, with notes on the ecology of arboreal crabs. Journal of Crustacean Biology 37(2): 157–167. https://doi.org/10.1093/jcbiol/rux012

Birch LC, Clark DP (1953) Forest soil as an ecological community with special reference to the fauna. The Quarterly Review of Biology 28(1): 13–36. https://doi.org/10.1086/399309

Bittelli M (2011) Measuring Soil Water Content: A Review. HortTechnology 21(3): 293–300. https://doi.org/10.21273/HORTTECH.21.3.293

Bliss DE (1968) Transition from water to land in decapod crustaceans. American Zoologist 8(3): 355–392. https://doi.org/10.1093/icb/8.3.355

Bliss DE (1979) From Sea to Tree: Saga of a land crab. American Zoologist 19(2): 385–410. https://doi.org/10.1093/icb/19.2.385

Bliss DE, Mantel LH (1968) Adaptations of crustaceans to land: A summary and analysis of new findings. American Zoologist 8(3): 673–685. https://doi.org/10.1093/icb/8.3.673

Bliss DE, Wang SME, Martinez EA (1966) Water Balance in the Land Crab, *Gecarcinus lateralis*, During the Intermolt Cycle. American Zoologist 6(2): 197–212. https://doi.org/10.1093/icb/6.2.197

Bliss LC, Courtin GM, Pattie DL, Riewe RR, Whitfield DWA, Widden P (1973) Arctic tundra ecosystems. Annual Review of Ecology, Evolution, and Systematics 4(1): 359–399. https://doi.org/10.1146/annurev.es.04.110173.002043

Bliss ED, Van Montfrans D, Van Montfrans M, Boyer JR (1978) Behavior and growth of the land crab *Gecarcinus lateralis* (Freminville) in southern Florida. Bulletin of the American Museum of Natural History 160: 111–152.

Bosc LAG (1802) Histoire Naturelle des vers Contenant Leur Description et Leurs Moeurs, Avec Figures Dessinées D'après Nature. Tome Premiere. De l'imprimerie de Guilleminet, chez Deterville, Paris, 324 pp. https://doi.org/10.5962/bhl.title.64025

Bouchon D, Zimmer M, Dittmer J (2016) The Terrestrial Isopod Microbiome: An All-in-One Toolbox for Animal–Microbe Interactions of Ecological Relevance. Frontiers in Microbiology 7: e1472. https://doi.org/10.3389/fmicb.2016.01472

Bousfield EL (1968) Terrestrial adaptations in Crustacea. Transition to land. American Zoologist 8: 393–398. https://doi.org/10.1093/icb/8.3.393

Boxshall GA, Kihara TC, Huys R (2016) Collecting and processing non-planktonic copepods. Journal of Crustacean Biology 36(4): 576–583. https://doi.org/10.1163/1937240X-00002438

Bracht G (1980) The jump of *Orchestia cavimana* Heller, 1865 (Crustacea, Amphipoda, Talitridae). Experientia 36(1): 56–57. https://doi.org/10.1007/BF02003968

Bright DR, Hogue CL (1972) A synopsis of the burrowing land crabs of the world and list of their arthropod symbionts and burrow associates. Los Angeles County Museum Contributions in Science 220: 1–58. https://doi.org/10.5962/p.241205

Bristowe WS (1941) The comity of spiders. Ray Society, London.

Bristowe WS (1958) The World of Spiders. Collins, U.K.

Britton JC, Kroh GC, Golighily C (1982) Biometric and ecological relationships in two sympatric Caribbean Gecarcinidae (Crustacea: Decapoda). Journal of Crustacean Biology 2(2): 207–222. https://doi.org/10.2307/1548000

Broly P, Mullier R, Deneubourg J-L, Devigne C (2012) Aggregation in woodlice: Social interaction and density effects. ZooKeys 176: 133–144. https://doi.org/10.3897/zookeys.176.2258

Broly P, Deville P, Maillet S (2013a) The origin of terrestrial isopods (Crustacea: Isopoda: Oniscidea). Evolutionary Ecology 27(3): 461–476. https://doi.org/10.1007/s10682-012-9625-8

Broly P, Deneubourg J-L, Devigne C (2013b) Benefits of aggregation in woodlice: A factor in the terrestrialization process? Insectes Sociaux 60(4): 419–435. https://doi.org/10.1007/s00040-013-0313-7

Broly P, Devigne L, Deneubourg J-L, Devigne C (2014) Effects of group size on aggregation against desiccation in woodlice (Isopoda: Oniscidea). Physiological Entomology 39(2): 165–171. https://doi.org/10.1111/phen.12060

Broly P, Mullier R, Devigne C, Deneubourg J-L (2016) Evidence of self-organization in a gregarious land-dwelling crustacean (Isopoda: Oniscidea). Animal Cognition 19(1): 181–192. https://doi.org/10.1007/s10071-015-0925-6

Brown IW, Fielder DR (1991) The Coconut Crab: Aspects of the Biology and Ecology of *Birgus latro* in the Republic of Vanuatu. ACIAR Monograph No.8, 136 pp.

Bruce AJ (1991) The "African" shrimp genus *Potamalpheops* in Australia, with the description of P. hanleyi, new species (Decapoda: Alpheidae). Journal of Crustacean Biology 11(4): 629–638. https://doi.org/10.2307/1548531

Bryant D, Crowther D, Papas P (2012) Improving survey methods and understanding the effects of fire on burrowing and spiny crayfish in the Bunyip and South Gippsland catchments. Black Saturday Victoria (2009) – Natural values fire recovery program. Victorian Government Department of Sustainability and Environment, Melbourne.

Bundhitwongrut T, Thirakhupt K, Pradatsundarasar A (2014) Population ecology of the land hermit crab *Coenobita rugosus* (Anomura, Coenobitidae) at Cape Panwa, Phuket Island, Andaman Coast of Thailand. The Natural History Bulletin of the Siam Society 60: 31–51.

Bureš S, Weidinger K (2003) Sources and timing of calcium intake during reproduction in flycatchers. Oecologia 137(4): 634–647. https://doi.org/10.1007/s00442-003-1380-7

Burggren WW, McMahon BR (1981) Haemolymph oxygen transport, acid–base status, and hydromineral regulation during dehydration in three terrestrial crabs, *Cardisoma*, *Birgus* and *Coenobita*. The Journal of Experimental Zoology 218(1): 53–64. https://doi.org/10.1002/jez.1402180107

Burggren WW, McMahon BR (1988) Biology of the Land Crabs. Cambridge University Press, Cambridge, 479 pp. https://doi.org/10.1017/CBO9780511753428

Burrows M, Hoyle G (1973) The mechanism of rapid running in the ghost crab, *Ocypode ceratophthalma*. The Journal of Experimental Biology 58(2): 327–349. https://doi.org/10.1242/jeb.58.2.327

Bursell E (1955) The transpiration of terrestrial Isopods. The Journal of Experimental Biology 32(2): 238–255. https://doi.org/10.1242/jeb.32.2.238

Camann MA, Lamoncha KL, Jones CB (2011) Oldgrowth redwood forest canopy arthropod prey base for arboreal Wandering Salamanders. A report to Save – the Redwoods League. Humboldt State University, Arcata, 23 pp.

Cameron JN (1981) Brief introduction to the land crabs of the Palau Islands: Stages in the transition to air breathing. The Journal of Experimental Zoology 218(1): 1–5. https://doi.org/10.1002/jez.1402180102

Cammaerts E, Mertens J (1999) A new genus and two new species of Chydoridae (Branchiopoda: Anomopoda), from Korup National Park, Cameroon. Belgian Journal of Zoology 129: 327–337.

Cannicci S, Ritossa S, Ruwa RK, Vannini M (1996) Tree-fidelity and hole-fidelity in the tree crab Sesarma leptosoma (Decapoda, Grapsidae). Journal of Experimental Marine Biology and Ecology 196: 299–311. https://doi.org/10.1016/0022-0981(95)00136-0

Capistrán-Barradas A, Defoeo O, Moreno-Casasola P (2003) Density and population structure of the red land crab *Gecarcinus lateralis* in a tropical semi-deciduous forest in Veracruz, Mexico. Interciencia 28: 323–345.

Capistrán-Barradas A, Moreno-Casasola P (2006) Postdispersal fruit and seed removal by the crab Gecarcinus lateralis in a coastal forest in Veracruz, Mexico. Biotropica 38(2): 1–7. https://doi.org/10.1111/j.1744-7429.2006.00116.x

Cardoso RS, Ria VA, Veloso G (2001) Embryonic development and reproductive strategy of *Pseudorchestoidea brasiliensis* (Amphipoda: Talitridae) at Prainha Beach, Brazil. Journal of Natural History 35(2): 201–211. https://doi.org/10.1080/00222930150215332

Carefoot TH (1993) Physiology of terrestrial isopods. Comparative Biochemistry and Physiology. Part A, Physiology 106(3): 413–429. https://doi.org/10.1016/0300-9629(93)90235-V

Carefoot TH, Taylor BE (1995) *Ligia*: a prototypal terrestrial isopod. In: Alikhan AM (Ed.) Terrestrial Isopod Biology. Balkema, Rotterdam, 47–60.

Carmona-Suárez CA (2011) Present status of *Cardisoma guanhumi* Latreille, 1828 (Crustacea: Brachyura: Gecarcinidae) populations in Venezuela. Interciencia 36: 908–913.

Carpenter KE, Niem VH [Eds] (1998) FAO species identification guide for fishery purposes.The living marine resources of the Western Central Pacific (Vol. 2). Cephalopods, crustaceans, holothurians and sharks. FAO, Rome, 687–1396.

Carson HL (1974) Three flies and three islands: Parallel evolution in *Drosophila*. Proceedings of the National Academy of Sciences of the United States of America 71(9): 3517–3521. https://doi.org/10.1073/pnas.71.9.3517

Carson HL, Wheeler MR (1973) A new crab fly from Christmas Island, Indian Ocean. Pacific Insects 15: 199–208.

Caubet Y, Juchault P, Mocquard JP (1998) Biotic triggers of female reproduction in the terrestrial isopod *Armadillidium vulgare* Latr. (Crustacea Oniscidea). Ethology Ecology & Evolution 10: 209–226. https://doi.org/10.1080/08927014.1998.9522853

Caubet Y, O'Farrell G, Lefebvre F (2008) Geographical variability of aggregation in terrestrial isopods: What is the actual significance of such behaviour? In: Zimmer M, Charfi-Cheikhrouha F, Taiti S (Eds) Proceedings of the International Symposium of TerrestrialIsopod Biology ISTIB–07. Shaker Verlag, Aachen, 175 pp.

Chace Jr FA (1972) Longevity of the West Indian terrestrial hermit crab *Coenobita clypeatus* (Herbst, 1791). Crustaceana 22: e320. https://doi.org/10.1163/156854072X00624

Chapman MA (1961) The terrestrial ostracod of New Zealand, *Mesocypris audax* sp. nov. Crustaceana 2(4): 255–261. https://doi.org/10.1163/156854061X00383

Chappuis PA (1928a) Zur Kenntnis der Mikrofauna van British Indien. 111. Copepoden Harpacticoiden. Indian Museum Review 30: 375–385. https://doi.org/10.26515/rzsi/v30/i4/1928/162553

Chappuis PA (1928b) Neue Harpacticiden aus Java. Treubia 10: 271–283.

Chappuis PA (1930) Copepoden Harpacticoiden von der Insel Luzon, Philippinen. Philippine Journal of Science 41: 143–147.

Chen J-Y, Vannier J, Huang D-Y (2001) The Origin of Crustaceans: New Evidence from the Early Cambrian of China. Proceedings of the Royal Society of London, Series B, Biological Sciences 268(1482): 2181–2187. https://doi.org/10.1098/rspb.2001.1779

Chen WJ, Hsu MJ, Cheng JH (2007) A new species of Alpine freshwater crab (Brachyura, Potamidae) from SiangYang National Forest Recreation Area, Taiwan. Crustaceana 80(8): 897–907. https://doi.org/10.1163/156854007781681292

Chiambeng GY, Dumont HJ (1999) New semi-terrestrial chydorids from the tropical rainforest of southwest Cameroon (Africa): *Nicsmirnovius camerounensis* n.gen. n.sp. and *Bryospilus africanus* n.sp (Crustacea: Anomopoda). Hydrobiologia 391(1/3): 257–264. https://doi.org/10.1023/A:1003606306093

Chou A, Lin C, Cronin TW (2020) Visual metamorphoses in insects and malacostracans: Transitions between an aquatic and terrestrial life. Arthropod Structure & Development 59: e100974. https://doi.org/10.1016/j.asd.2020.100974

Cividini S, Sfenthourakis S, Montesanto G (2020) Are terrestrial isopods able to use stridulation and vibrational communication as forms of intra and interspecific signaling and defense strategies as insects do? A preliminary study in *Armadillo officinalis*. Naturwissenschaften 107(1): 1–4. https://doi.org/10.1007/s00114-019-1656-3

Cloudsley-Thompson JL (1956) XXXIII.—Studies in diurnal rhythms.—VI. Bioclimatic observations in Tubisia and their significance in relation to the physiology of the fauna, especially woodlice, centipedes, scorpions and beetles. Annals & Magazine of Natural History 9(101): 305–329. https://doi.org/10.1080/00222935608655817

Cloudsley-Thompson JL (1975) Adaptations of Arthropoda to arid environments. Annual Review of Entomology 20(1): 261–283. https://doi.org/10.1146/annurev.en.20.010175.001401

Cloudsley-Thompson JL (1988) The Conquest of the Land by Crustacea. Evolution and Adaptation of Terrestrial Arthropods. Springer, Berlin, 135 pp. https://doi.org/10.1007/978-3-642-61360-9_9

Conran JG, Bradbury JH (2007) Aspidistras, amphipods and Oz: Niche opportunism between strangers in a strange land. Plant Species Biology 22(1): 41–48. https://doi.org/10.1111/j.1442-1984.2007.00174.x

Corgosinho PHC, Mercado-Salas NF, Martínez Arbizu P, Santos-Silva EN, Khihara TC (2017) Revision of the *Remaneicaris argentina*-group (Copepoda, Harpacticoida, Parastenocarididae): Supplementary description of species, and description of the first semi–terrestrial *Remaneicaris* from the tropical forest of Southeast Mexico. Zootaxa 4238(4): 499–530. https://doi.org/10.11646/zootaxa.4238.4.2

Coughtrey PJ, Martin MH, Chard J, Shales SW (1980) Microorganisms and metal retention in the woodlouse *Oniscus asellus*. Soil Biology & Biochemistry 12(1): 23–27. https://doi.org/10.1016/0038-0717(80)90098-X

Cowling JE, Spicer JI, Weeks JM, Gaston KJ (2003) Environmental tolerances of an invasive terrestrial amphipod, *Arcitalitrus dorrieni* (Hunt) in Britain. Comparative Biochemistry and Physiology. Part A, Molecular & Integrative Physiology 136(3): 735–747. https://doi.org/10.1016/S1095-6433(03)00242-3

Cowling JE, Spicer JI, Weeks JM, Gaston KJ (2004) Physiological tolerances of the euterrestrial amphipod *Arcitalitrus dorrieni* (Hunt) as a key to its geographical distribution? A test using mesocosms. Comparative Biochemistry and Physiology. Part A, Molecular & Integrative Physiology 139(2): 251–259. https://doi.org/10.1016/j.cbpb.2004.09.011

Csonka D, Halasy K, Szabó P, Mrak P, Štrus J, Hornung E (2013) Eco-morphological studies on pleopodal lungs and cuticle in *Armadillidium* species (Crustacea, Isopoda, Oniscidea). Arthropod Structure & Development 42(3): 229–235. https://doi.org/10.1016/j.asd.2013.01.002

Csonka D, Halasy K, Hornung E (2015) Histological studies on the marsupium of two terrestrial isopods (Crustacea, Isopoda, Oniscidea). ZooKeys 515: 81–92. https://doi.org/10.3897/zookeys.515.9401

Cumberlidge N, Clark PF (2010) A redescription of *Potamonautes loveni* (Colosi, 1924), a medically important freshwater crab from western Kenya and eastern Uganda, East Africa (Brachyura: Potamoidea: Potamonautidae). In: Castro P, Davie PJF, Ng PKL, Richer de Forges B (Eds) Studies on Brachyura: A homage to Danièle Guinot. Crustaceana Monographs 11: 61–74. https://doi.org/10.1163/ej.9789004170865.i-366.47

Cumberlidge N, Fenolio DB, Walvoord ME, Stout J (2005) Tree-climbing crabs (Potamonautidae and Sesarmidae) from phytotelmic microhabitats in rainforest canopy in Madagascar. Journal of Crustacean Biology 25(2): 302–308. https://doi.org/10.1651/C-2532

Daday E (1910) Untersuchungen Uber die Süsswasser-Mikrofauna Deutsch–Ostafrikas. Zoologica 23(59): 1–314. https://doi.org/10.5962/bhl.title.11655

Dahms HU, Qian PY (2004) Life histories of the Harpacticoida (Copepoda, Crustacea): A comparison with meiofauna and macrofauna. Journal of Natural History 38(14): 1725–1734. https://doi.org/10.1080/0022293031000156321

David JF, Handa IT (2010) The ecology of saprophagous macroarthropods (millipedes, woodlice) in the context of global change. Biological Reviews of the Cambridge Philosophical Society 85: 881–895. https://doi.org/10.1111/j.1469-185X.2010.00138.x

David JF, Devernay S, Loucougaray G, Le Floch E (1999) Belowground biodiversity in a Mediterranean landscape: Relationships between saprophagous macroarthropod communities and vegetation structure. Biodiversity and Conservation 8(6): 753–767. https://doi.org/10.1023/A:1008842313832

De Deckker P (1983) Terrestrial Ostracods in Australia. Papers from the Conference on the Biology and Evolution of Crustacea. Australian Museum Memoir 18: 87–100. https://doi.org/10.3853/j.0067-1967.18.1984.374

De Grave S, Pentcheff ND, Ahyong ST, Chan T-Y, Crandall KA, Dworschak PC, Felder DL, Feldmann RM, Fransen CHJM, Goulding LYD, Lemaitre R, Low MEY, Martin JW, Ng PKL, Schweitzer CE, Tan SH, Wetzer R (2009) A classification of living and fossil genera of decapod crustaceans. The Raffles Bulletin of Zoology (Suppl. 21): 1–109.

Deevey ES (1941) Notes on the encystment of the harpacticoid copepod *Canthocamptus staphylinoides* Pearse. Ecology 22(2): 197–200. https://doi.org/10.2307/1932216

Degener O, Gillaspy E (1955) Canton Island, South Pacific. Atoll Research Bulletin 41: 1–51. https://doi.org/10.5479/si.00775630.41.1

Dejean A (1997) Distribution of colonies and prey specialization in the ponerine ant genus *Leptogenys* (Hymenoptera: Formicidae). Sociobiology 29: 293–299.

Dejean A, Evraerts C (1997) Predatory behavior in the genus *Leptogenys*: A comparative study. Journal of Insect Behavior 10(2): 177–191. https://doi.org/10.1007/BF02765551

Dela-Cruz J, Morris S (1997a) Respiratory, acid-base, and metabolic responses of the Christmas Island blue crab, *Cardisoma hirtipes* (Dana), during simulated environmental conditions. Physiological Zoology 70(1): 100–115. https://doi.org/10.1086/639552

Dela-Cruz J, Morris S (1997b) Water and ion balance, and nitrogenous excretion as limitations to aerial excursion in the Christmas Island blue crab, *Cardisoma hirtipes* (Dana). The Journal of Experimental Zoology 279(6): 537–548. https://doi.org/10.1002/(SICI)1097-010X(19971215)279:6<537::AID-JEZ1>3.0.CO;2-O

Delfosse B (1990) The effect of the red land crab, *Gecarcinus lateralis*, on the litter layer, nutrient availability and seedling recruitment in a semi-deciduous seasonal tropical forest. Thesis. York University, Toronto, 199 pp.

Delhoumi M, Catania V, Zaabar W, Tolone M, Quatrini P, Achouri MS (2020) The gut microbiota structure of the terrestrial isopod *Porcellionides pruinosus* (Isopoda: Oniscidea), The European Zoological Journal 87: 357–368. [1.] https://doi.org/10.1080/24750263.2020.1781269

Deslippe RJ, Jelinski L, Eisner T (1996) Defense by use of a proteinaceous glue: Woodlice vs. ants. Zoology 99: 205–210.

Detto T (2007) The fiddler crab *Uca mjoebergi* uses colour vision in mate choice. Proceedings of the Royal Society B, Biological Sciences 274(1627): 2785–2790. https://doi.org/10.1098/rspb.2007.1059

Detto T, Backwell P (2009) The fiddler crab *Uca mjoebergi* uses ultraviolet cues in mate choice but not aggressive interactions. Animal Behaviour 78(2): 407–411. https://doi.org/10.1016/j.anbehav.2009.05.014

Detto T, Backwell P, Hemmi JM, Zeil J (2006) Visually mediated species and neighbour recognition in fiddler crabs (*Uca mjoebergi* and *Uca capricomis*). Proceedings of the Royal Society B, Biological Sciences 273(1594): 1661–1666. https://doi.org/10.1098/rspb.2006.3503

Devigne C, Broly P, Deneubourg J-L (2011) Individual preferences and social interactions determine the aggregation of woodlice. PLoS ONE 6(2): e17389. hhttps://doi.org/10.1371/journal.pone.0017389

Diesel R (1989) Parental care in an unusual environment: *Metopaulias depressus* (Decapoda: Grapsidae), a crab that lives in epiphytic bromeliads Article in Animal Behaviour 38(4): 561–575. https://doi.org/10.1016/S0003-3472(89)80001-6

Diesel R, Horst D (1995) Breeding in a Snail Shell: Ecology and Biology of the Jamaican Montane Crab *Sesarma jarvisi* (Decapoda: Grapsidae). Journal of Crustacean Biology 15(1): 179–195. https://doi.org/10.2307/1549020

Diesel R, Schubart CD (2000) Die außergewöhnliche Evolutionsgeschichte jamaikanischer Felsenkrabben. Biologie in Unserer Zeit 30(3): 136–147. https://doi.org/10.1002/(SICI)1521-415X(200003)30:3<136::AID-BIUZ136>3.0.CO;2-R

Diesel R, Schubart CD (2007) The social breeding system of the Jamaican bromeliads crab, *Metopaulias depressus*. In: Duffy JE, Thiel M (Eds) Evolutionary Ecology of Social and Sexual Systems: Crustacea as Model Organisms. Oxford University Press, Oxford, 365–386. https://doi.org/10.1093/acprof:oso/9780195179927.003.0017

Diesel R, Schuh M (1993) Maternal care in the bromeliad crab *Metopaulias depressus* (Decapoda): Maintaining oxygen, pH and calcium levels optimal for the larvae. Behavioral Ecology and Sociobiology 32(1): 11–15. https://doi.org/10.1007/BF00172218

Do VT, Shih H-T, Huang C (2016) A New Species of Freshwater Crab of the Genus *Tiwaripotamon* Bott, 1970 (Crustacea, Brachyura, Potamidae) from northern Vietnam and southern China. The Raffles Bulletin of Zoology 64: 187–193.

Dobson M (2004) Freshwater crabs in Africa. Freshwater Forum 21: 3–26.

Dobson M, Magana AM, Mathooko JM, Ndegwa FK (2007) Distribution and abundance of freshwater crabs (*Potamonautes* spp.) in rivers draining Mt Kenya, East Africa. Fundamental and Applied Limnology. Archiv für Hydrobiologie 168(3): 271–279. https://doi.org/10.1127/1863-9135/2007/0168-0271

Downes JA (1966) Observations on the Mating Behaviour of the Crab Hole Mosquito *Deinocerites cancer* (Diptera: Culicidae). Canadian Entomologist 98(11): 1169–1177. https://doi.org/10.4039/Ent981169-11

Dresel EIB, Moyle V (1950) Nitrogenous excretion of amphipods and isopods. The Journal of Experimental Biology 27(2): 210–225. https://doi.org/10.1242/jeb.27.2.210

Drew MM, Harzsch S, Stensmyr M, Erland S, Hansson BS (2010) A review of the biology and ecology of the Robber Crab, *Birgus latro* (Linnaeus, 1767) (Anomura: Coenobitidae). Zoologischer Anzeiger 249(1): 45–67. https://doi.org/10.1016/j.jcz.2010.03.001

Drew MM, Smith MJ, Hansson BS (2013) Factors influencing growth of giant terrestrial robber crab *Birgus latro* (Anomura: Coenobitidae) on Christmas Island. Aquatic Biology 19(2): 129–141. https://doi.org/10.3354/ab00523

Dubinsky Z, Steinberger Y, Shachak M (1979) The survival of the desert isopod *Hemilepistus reaumurii* (Audouin) in relation to temperature (Isopoda, Oniscoidea). Crustaceana 36(2): 147–154. https://doi.org/10.1163/156854079X00339

Dumont HJ, Maas S (1988) Five new species of leaf litter harpacticoids (Crustacea, Copepoda) from Nepal. Zoologica Scripta 17(1): 55–68. https://doi.org/10.1111/j.1463-6409.1988.tb00086.x

Duncan KW (1985) A critique of the concept of genetic assimilation as a mechanism in the evolution of terrestrial talitrids (Amphipoda). Canadian Journal of Zoology 63(9): 2230–2232. https://doi.org/10.1139/z85-330

Duncan KW (1994) Terrestrial Talitridae (Crustacea: Amphipoda). Fauna of New Zealand 31: 1–125.

Dunham DW, Gilchrist SL (1988) Behavior. In: Burggren WW, McMahon BR (Eds) Biology of the Lund Crabs. Cambridge University Press, Cambridge, 97–138. https://doi.org/10.1017/CBO9780511753428.005

Dunlop JA, Scholtz G, Selden PA (2013) Water-to-land Transitions, Arthropod Biology and Evolution. Springer, 417–439. https://doi.org/10.1007/978-3-662-45798-6_16

Dutton A-J (2017a) Technical report on that status of the subpopulations and habitat preferences of the Spiky Yellow Woodlouse *Pseudolaureola atlantica*. Saint Helena National Trust.

Dutton A-J (2017b) Spiky Yellow Woodlouse Ecology and Habitat. Saint Helena National Trust.

Edney EB (1954) Woodlice and the land habitat. Biological Reviews of the Cambridge Philosophical Society 29(2): 185–219. https://doi.org/10.1111/j.1469-185X.1954.tb00595.x

Edney EB (1964) Acclimation to Temperature in Terrestrial Isopods: I. Lethal Temperatures. Physiological Zoology 37(4): 364–377. https://doi.org/10.1086/physzool.37.4.30152755

Edney E (1968) Transition from water to land in isopod crustaceans. American Zoologist 8(3): 309–326. https://doi.org/10.1093/icb/8.3.309

Edney EB, Allen W, McFarlane J (1974) Predation by terrestrial isopods. Ecology 55(2): 428–433. https://doi.org/10.2307/1935231

Ehrhardt JP, Niaussat P (1970) Ecologie et physiologie du brachyoure terrestre *Gecarcinus planatus* Stimpson (Dapres les individus de L'Atoll de Clipperton). Bulletin de la Société Zoologique de France 95(1): 41–54.

Erickson AA, Saltis M, Bell SS, Dawes CJ (2003) Herbivore feeding preferences as measured by leaf damage and stomatal ingestion: A mangrove crab example. Journal of Experimental Marine Biology and Ecology 289: 123–138. https://doi.org/10.1016/S0022-0981(03)00039-X

Ernst F, Fabritius H-O, Griesshaber E, Reisecker C, Neues F, Epple M, Schmahl WW, Hild S, Ziegler A (2020) Functional adaptations in the tergite cuticle of the desert isopod *Hemilepistus reaumuri* (Milne-Edwards, 1840). Journal of Structural Biology 212(1): 107570–107570. https://doi.org/10.1016/j.jsb.2020.107570

Eutrópio FJ, Krohling W (2013) First record of Amphipoda *Talitroides topitotum* (Burt, 1934) (Gammaridea, Talitridae) in the State of Espírito Santo, Brazil. Acta Scientiarum. Biological Sciences. Maringá 35 (1): 37–39. https://doi.org/10.4025/actascibiolsci.v35i1.12447

Farrelly CA, Greenaway P (1992) Morphology and ultrastructure of the gills of terrestrial crabs (Crustacea, Gecarcinidae and Grapsidae): Adaptations for air-breathing. Zoomorphology 112(1): 39–49. https://doi.org/10.1007/BF01632993

Farrelly CA, Greenaway P (1993) Land crabs with smooth lungs: Grapsidae, Gecarcinidae, and Sundathelphusidae ultrastructure and vasculature. Journal of Morphology 215(3): 245–260. https://doi.org/10.1002/jmor.1052150306

Farrelly CA, Greenaway P (1994) Gas exchange through the lungs and gills in air-breathing crabs. The Journal of Experimental Biology 187(1): 113–130. https://doi.org/10.1242/jeb.187.1.113

Farrelly CA, Greenaway P (2005) The morphology and vasculature of the respiratory organs of terrestrial hermit crabs (*Coenobita* and *Birgus*): Gills, branchiostegal lungs and abdominal lungs. Arthropod Structure & Development 34(1): 63–87. https://doi.org/10.1016/j.asd.2004.11.002

Favretto MR, Paoletti MG, Lorenzoni GG, Dioli E (1988) Lo scambio di invertebrati tra un relitto di bosco planiziale ed agroecosistemi contigui. L'artropodofauna del bosco di Lison. Nova Thalassia, 329–358.

Federici BA (1984) Diseases of terrestrial isopods. In: Sutton SL, Holdich DM (Eds) The Biology of Terrestrial Isopods. The Zoological Society of London. Clarendon Press, Oxford, UK, 233–244.

Ferrara F, Maschwitz U, Steghaus Kovac S, Taiti S (1988) The genus *Exalloniscus* Stebbing, 1911 (Crustacea, Oniscidea) and its relationship with social insects. Pubblicazioni dell'Istituto di Entomologia dell'Università di Pavia 36 (1987): 43–46.

Ferrara F, Paoli P, Taiti S (1997) An original respiratory structure in the xeric genus *Periscyphis* Gerstaecker, 1873 (Crustacea: Oniscidea: Eubelidae). Zoologischer Anzeiger 235: 147–156.

Fiers F (2013) *Bryocamptus* (*Bryocamptus*) *gauthieri* (Roy, 1924): a Mediterranean edaphic specialist (Crustacea: Copepoda: Harpacticoida). Revue Suisse de Zoologie 120(3): 357–371.

Fiers F, Ghenne V (2000) Cryptozoic copepods from Belgium: Diversity and biogeographic implications. Belgian Journal of Zoology 130: 11–19.

Fiers F, Jocque M (2013) Leaf litter copepods from a cloud forest mountaintop in Honduras (Copepoda: Cyclopidae, Canthocamptidae). Zootaxa 3630(2): 270–290. https://doi.org/10.11646/zootaxa.3630.2.4

Fimpel E (1975) Phanomene landadaptation bei terrestrischen und semiterrestrichen Brachyura der Brasilianschen Kuste (Malacostraca, Decapoda). Zoologische Jahrbucher. Abteilung fur Systematik, Ökologie und Geographie der Tiere 102: 173–214.

Firmo AM, Tognella MM, Silva SR, Alves RRN (2012) Capture and commercialization of blue land crabs ("*guaiamum*") *Cardisoma guanhumi* (Lattreille, 1825) along the coast of Bahia State, Brazil: An ethnoecological approach. Journal of Ethnobiology and Ethnomedicine 8(1): 1–12. https://doi.org/10.1186/1746-4269-8-12

Fišer C (2019) *Niphargus*: A Model System for Evolution and Ecology. In: White WB, Culver DC (Eds) Encyclopedia of cave (2nd edn.). Elsevier. https://doi.org/10.1016/B978-0-12-383832-2.00082-7

Fittkau EJ, Klinge H (1973) On biomass and trophic structure of the central Amazonian rain forest ecosystem. Biotropica 5(1): 2–14. https://doi.org/10.2307/2989676

Fitzpatrick Jr JF (1975) The taxonomy and biology of theprairie crawfishes, *Procambarus hagenianus* (Faxon) andallies. Freshwater Crayfish 2: 381–389.

Fletcher WL, Brown IW, Fielder DR (1990) Growth of the coconut crab *Birgus latro* in Vanuatu. Journal of Experimental Marine Biology and Ecology 141: 63–78. https://doi.org/10.1016/0022-0981(90)90158-9

Florey E, Hoyle G (1976) The efects of temperature on a nerve-muscle system of the Hawaiian ghost crab, *Ocypode ceratophthalma* (Pallas). Journal of Comparative Physiology 110(1): 51–64. https://doi.org/10.1007/BF00656781

Flössner D (1992) A new genus and a new species of freshwater Canthocamptidae (Copepoda: Harpacticoida) from wet mosses of Canada. Hydrobiologia 234(1): 7–14. https://doi.org/10.1007/BF00010774

Fraenkel G, Gunn DL (1961) The Orientation of Animals. Monographs in Animal Behaviour. Dover Publications, Oxford / New York, 376 pp.

Frey D (1980) The non-swimming chydorid Cladocera of wet forests, with descriptions of a new genus and two new species. Internationale Revue der Gesamten Hydrobiologie 65(5): 613–641. https://doi.org/10.1002/iroh.19800650502

Friedlander CP (1964) Thigmokinesis in woodlice. Animal Behaviour 12(1): 164–174. https://doi.org/10.1016/0003-3472(64)90118-6

Friend JA (1975) A study of energy flow through a natural population of euterrestrial amphipods. Honors Thesis, University of Tasmania, Hobart, Tasmania.

Friend JA, Lam PKS (1985) Occurrence of the terrestrial amphipod *Talitroides topitotum* (Burt) on Hong Kong Island. Acta Zootaxonomica Sinica 10: 27–33.

Friend JA, Richardson AMM (1986) Biology of terrestrial amphipods. Annual Review of Entomology 31(1): 25–48. https://doi.org/10.1146/annurev.en.31.010186.000325

Furse JM, Wild CH (2002) Terrestrial activities of Euastacus sulcatus, the Lamington Spiny Crayfish (Short Communication). Freshwater Crayfish 13: e604.

Garces HA (1988) Desiccation tolerance of *Platorchestia platensis* (Krøyer, 1845) (Amphipoda, Talitridae). Revista de Biología Tropical 36: 63–66.

Garcia-Franco JG, Rico-Gray V, Zayas O (1991) Seed and seedling predation of *Bromelia penquin* L. by the red land crab *Gecarcinus lateralis* Frem. in Veracruz, Mexico. Biotropica 23: 96–97. https://doi.org/10.2307/2388695

Garwood RJ, Edgecombe GD (2011) Early terrestrial animals, evolution, and uncertainty. Evolution 4(3): 489–50. https://doi.org/10.1007/s12052-011-0357-y

Gaston KJ, Spicer JI (1998) Do upper thermal tolerances differ in geographically separated populations of the beachflea *Orchestia gammarellus* (Crustacea: Amphipoda)? Journal of Experimental Marine Biology and Ecology 229(2): 265–276. https://doi.org/10.1016/S0022-0981(98)00057-4

Ghilarov MS (1956) Soil as the environment of the invertebrate transition from the aquatic to the terrestrial life – Sixth International Congress of Soil Sciences, Paris, 1956, Commission III. 51: 307–313.

Ghiradella HT, Case JF, Cronshaw J (1968a) Fine structure of the aesthetasc hairs of *Coenobita compressus* Edwards. Journal of Morphology 124(3): 361–385. https://doi.org/10.1002/jmor.1051240309

Ghiradella HT, Case JF, Cronshaw J (1968b) Structure of aesthetascs in selected marine and terrestrial decapods: Chemoreceptor morphology and environment. American Zoologist 8(3): 603–621. https://doi.org/10.1093/icb/8.3.603

Gifford CA (1962) Some observations on the general biology of the land crab, *Cardisoma guanhumi* (Latreille), in south Florida. The Biological Bulletin 123(1): 207–223. https://doi.org/10.2307/1539516

Giurginca A, Baba ŞC, Munteanu C-M (2017) New data on the Oniscidea, Diplopoda and Chilopoda from the urban parks of Bucharest. North-Western Journal of Zoology 13: 234–243.

Glazier DS, Kleynhans E (2015) Arboreal herbivory by a semi–terrestrial South African isopod crustacean, *Tylos capensis* Krauss (Isopoda: Tylidae), on the bietou bush, *Chrysanthemoides monilifera* (L.) Norlindh. African Invertebrates 56(3): 729–738. https://doi.org/10.5733/afin.056.0315

Glime JM (2017a) Arthropods: Crustacea – Copepoda and Cladocera. Chapt. 10–1. In: Glime JM (Ed.) Bryophyte Ecology (Vol. 2). Bryological Interaction. Ebook sponsored by Michigan Technological University and the International Association of Bryologists. http://digitalcommons.mtu.edu/bryophyte–ecology2/

Glime JM (2017b) Invertebrates: Introduction. Chapt. 4–1. In: Glime JM (Ed.) Bryophyte Ecology (Vol. 2). Bryological 4–1–1. Interaction. Ebook sponsored by Michigan Technological University and the International Association of Bryologists.

Godfrey GK, Crowcroft P (1960) The Life of the Mole (*Talpa europaea* L.). Museum Press, London.

Goettel MS, Toohey MK, Engber BR, Pillai JS (1981) A modified garden sprayer for sampling crab hole water. Mosquito News 41: 789–790.

Golonka J, Ford D (2000) Pangean (Late Carboniferous–Middle Jurassic) paleoenvironment and lithofacies. Palaeogeography, Palaeoclimatology, Palaeoecology 161(1–2): 1–34. https://doi.org/10.1016/S0031-0182(00)00115-2

Gómez LD (1977) La mosca del cangrejo terrestre Cardisoma crassum Smith (Crustacea: Gecarcinidae) en la Isla del Coco, Costa Rica. Revista de Biología Tropical 25(1): 59–63.

Gongalsky KB, Savin FA, Pokarzhevskii AD, Filimonova ZV (2005) Spatial distribution of isopods in an oak-beech forest. European Journal of Soil Biology 41(3–4): 117–122. https://doi.org/10.1016/j.ejsobi.2005.09.012

Gorvett H (1956) Tegumental glands and terrestrial life in woodlice. Proceedings of the Zoological Society of London 126(2): 291–314. https://doi.org/10.1111/j.1096-3642.1956.tb00439.x

Govender Y, Sabat A, Cuevas E (2008) Effect of land use/land cover changes on land crab, *Cardisoma guanhumi*, abundance in Porto Rico. Journal of Tropical Ecology 24(4): 417–423. https://doi.org/10.1017/S0266467408005130

Graham ZA, Diehl KM, Davis D, Loughman ZJ (2022) Death from below: Sit-and-wait predatory behavior in a burrowing crayfish (*Lacunicambarus thomai*). Food Webs 31: e00225. https://doi.org/10.1016/j.fooweb.2022.e00225

Green J (1959) Haemoglobin and the habitat of the harpacticoid copepod *Elaphoidella gracilis* (Sars). Nature 183(4678): e1834. https://doi.org/10.1038/1831834a0

Green PT (1997) Red crabs in rain forest on Christmas Island, Indian Ocean – Activity patterns, density and biomass. Journal of Tropical Ecology 13(1): 17–38. https://doi.org/10.1017/S0266467400010221

Green PT (2004) Burrow Dynamics of the Red Land Crab *Gecarcoidea natalis* (Brachyura, Gecarcinidae) in Rain Forest on Christmas Island (Indian Ocean). Journal of Crustacean Biology 24(2): 340–349. https://doi.org/10.1651/C-2447

Green PT, O'Dowd DJ, Lake PS (1997) Control of seedling recruitment by land crabs in rain forest on a remote oceanic island. Ecology 78(8): 2474–2486. https://doi.org/10.1890/0012-9658(1997)078[2474:COSRBL]2.0.CO;2

Green PT, Lake PS, O'Dowd DJ (1999) Monopolization of litter processing by a dominant land crab on a tropical oceanic island. Oecologia 119(3): 435–444. https://doi.org/10.1007/s004420050805

Green PT, Comport S, Slip D (2004) The Management and Control of the Invasive Alien Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean: Aerial Baiting Campaign September 2002. Unpublished final report to Environment Australia and the Crazy Ant Steering Committee. Monash University, Melbourne, 79 pp.

Green PT, O'Dowd DJ, Lake PS (2008) Recruitment dynamics in a rainforest seedling community: Context-independent impact of a keystone consumer. Oecologia 156(2): 373–385. https://doi.org/10.1007/s00442-008-0992-3

Greenaway P (1994) Salt and Water Balance in Field Populations of the Terrestrial Crab *Gecarcoidea natalis*. Journal of Crustacean Biology 14(3): 438–453. https://doi.org/10.2307/1548991

Greenaway P (1988) Ion and Water Balance. In: Burggren WW, McMahon BR (Eds) Biology of Land Crabs. Cambridge University Press, New York, 211–248. https://doi.org/10.1017/CBO9780511753428.008

Greenaway P (1999) Physiological diversity and the colonisation of land. In: Schram FR, von Vaupel Klein JC (Eds) Proceedings of the Fourth International Crustacean Congress, Amsterdam, the Netherlands, July 20–24, 1998 (Vol. I). Brill Academic Publishers, Leiden, 823–842.

Greenaway P (2001) Sodium and water balance in free ranging robber crabs, *Birgus latro* (Anomura: Coenobitidae) on Christmas Island. Journal of Crustacean Biology 21(2): 317–327. https://doi.org/10.1163/20021975-99990131

Greenaway P (2003) Terrestrial adaptations in the Anomura (Crustacea: Decapoda). Memoirs of the Museum of Victoria 60(1): 13–26. https://doi.org/10.24199/j.mmv.2003.60.3

Greenaway P, MacMillen RE (1978) Salt and Water Balance in the Terrestrial Phase of the Inland Crab *Holthuisana* (*Austrothelphusa*) *transversa* Martens (Parathelphusoidea: Sundathelphusidae). Physiological Zoology 51(3): 217–229. https://doi.org/10.1086/physzool.51.3.30155739

Greenaway P, Morris S (1989) Adaptations to a terrestrial existence by the robber crab, *Birgus latro*. III. Nitrogenous excretion. The Journal of Experimental Biology 143(1): 333–346. https://doi.org/10.1242/jeb.143.1.333

Greenaway P, Morris S, McMahon BR (1988) Adaptations to a terrestrial existence by the robber crab *Birgus latro*. II. *In vivo* respiratory gas exchange and transport. The Journal of Experimental Biology 140(1): 493–509. https://doi.org/10.1242/jeb.140.1.493

Greenaway P, Taylor HH, Morris S (1990) Adaptations to a terrestrial existence by the robber crab, *Birgus latro*. VI. The role of the excretory system in fluid balance. The Journal of Experimental Biology 152(1): 505–519. https://doi.org/10.1242/jeb.152.1.505

Greenslade P, Melbourne BA, Davies KF, Stevens MI (2008) The status of two exotic terrestrial Crustacea on sub-Antarctic Macquarie Island. The Polar Record 44(1): 15–23. https://doi.org/10.1017/S0032247407006778

Griffiths BS, Wood S, Cheshire MV (1989) Liberalization of ^{14}C labelled plant material by Porcellio scaber (Crustacea: Isopoda). Pedobiologia 33: 355–360.

Griffiths ME, Basma M, Vega A (2007) Dry season distribution of land crabs, *Gecarcinus quadratus* (Crustacea: Gecarcinidae), in Corcovado National Park, Costa Rica. Revista de Biología Tropical 55(1): 219–224. https://doi.org/10.15517/rbt.v55i1.6073

Griffiths HM, Ashton LA, Parr CL, Eggleton P (2021) The impact of invertebrate decomposers on plants and soil. The New Phytologist 231(6): 2142–2149. https://doi.org/10.1111/nph.17553

Grimaldi DA (2010) 400 million years on six legs: On the origin and early evolution of Hexapoda. Arthropod Structure & Development 39(2–3): 191–203. https://doi.org/10.1016/j.asd.2009.10.008

Grinang J, Min PY, Ng PKL (2015) A new species of tree–hole dwelling freshwater crab of the genus *Arachnothelphusa* Ng, 1991 (Crustacea: Decapoda: Brachyura: Gecarcinucidae) from northern Sarawak, Malaysia, Borneo. The Raffles Bulletin of Zoology 63: 454–460.

Grosso LE, Peralta M (2009) A new Paraleptamphopidae (Crustacea Amphipoda) in the burrow of *Virilastacus rucapihuelensis* (Parastacidae) and surrounding peat bogs. *Rudolphia macrodactylus* n. gen., n. sp. from southern South America. Zootaxa 2243(1): 40–52. https://doi.org/10.11646/zootaxa.2243.1.2

Growns IO, Richardson AMM (1988) The diet and burrowing habits of the freshwater crayfish *Parastacoides tasmanicus tasmanicus* Clark (Decapoda: Parastacidae).

Australian Journal of Marine and Freshwater Research 39(4): 525–534. https://doi.org/10.1071/MF9880525

Guiaşu RC (2007) Conservation and diversity of the crayfishes of the genus *Fallicambarus* Hobbs, 1969 (Decapoda, Cambaridae), with an emphasis on the status of *Fallicambarus fodiens* (Cottle, 1863) in Canada. Crustaceana 80(2): 207–223. https://doi.org/10.1163/156854007780121438

Gunnarsson T, Sundin P, Tunlid A (1988) Importance of leaf litter fragmentation for bacterial growth. Oikos 52(3): 303–308. https://doi.org/10.2307/3565203

Gutiérrez JL, Jones CL, Groffman PM, Findlay SG, Iribane OO, Ribeiro PD, Bruschetti CM (2006) The contribution of crab burrow excavation to carbon availability in surficial salt-marsh sediments. Ecosystems 9(4): 647–658. https://doi.org/10.1007/s10021-006-0135-9

Gómez LD (1977) La mosca del cangrejo terrestre *Cardisoma crassum* Smith (Crustacea: Gecarcinidae) en la Isla del Coco, Costa Rica. Revista de Biología Tropical 25: 59–63.

Hadley NF, Quinlan MC (1984) Cuticular transpiration in the isopod *Porcellio laevis*: chemical and morphological factors involved in its control. Symposium of the Zoological Society of London 53: 97–107.

Hahn HJ (2002) Methods and difficulties of sampling stygofauna – an overview. In: Breh W, Gottlieb J, Hötzl H, Kern F, Liesch T, Niessner R (Eds) Proceedings of the Second International Conference and Industrial Exhibition "Field Screening Europe 2001", Kluwer Academic Publishers, Dordrecht, 201–206. https://doi.org/10.1007/978-94-010-0564-7_32

Hallberg E, Skog M (2011) Chemosensory sensilla in crustaceans. In: Breithaupt T, Thiel M (Eds) Chemical Communication in Crustaceans Springer, New York, 103–121. https://doi.org/10.1007/978-0-387-77101-4_6

Handa IT, Aerts R, Berendse F, Berg MP, Bruder A, Butenschoen O, Chauvet E, Gessner MO, Jabiol J, Makkonen M, McKie BG, Malmqvist B, Peeters ETHM, Scheu S, Schmid B, van Ruijven J, Vos VCA, Hättenschwiler S (2014) Consequences of biodiversity loss for litter decomposition across biomes. Nature 509(7499): 218–221. https://doi.org/10.1038/nature13247

Hansson L-A, Dartnall HJG, Ellis-Evans JC, MacAlister H, Tranvik LJ (1996) Variation in physical, chemical and biological components in the subAntarctic lakes of South Georgia. Ecography 19(4): 393–403. https://doi.org/10.1111/j.1600-0587.1996.tb00250.x

Hansson BS, Harzsch S, Knaden M, Stensmyr MC (2011) The neural and behavioral basis of chemical communication in terrestrial crustaceans. In: Breithaupt T, Thiel M (Eds) Chemical Communication in Crustaceans. Springer, New York, 149–173. https://doi.org/10.1007/978-0-387-77101-4_8

Harding JP (1953) The first known example of a terrestrial ostracod, *Mesocypris terrestris* sp. nov. Annals of the Natal Museum 12: 359–365.

Harding JP (1955) The Evolution of Terrestrial Habits in an Ostracod. Bull. VII, Symposium on Organic Evolution, National Institute of Sciences of India, New Delhi, 104–106.

Hartenstein R (1964) Feeding, digestion, glycogen and the environmental conditions of the digestive system in *Oniscus asellus*. Journal of Insect Physiology 10(4): 611–621. https://doi.org/10.1016/0022-1910(64)90031-9

Hartenstein R (1982) Soil macroinvertebrates, aldehyde oxidase, catalase, cellulase and peroxidase. Soil Biology & Biochemistry 14(4): 387–391. https://doi.org/10.1016/0038-0717(82)90010-4

Hartnoll RG, Clark PF (2006) A mass recruitment event in the land crab *Gecarcinus ruricola* (Linnaeus, 1758) (Brachyura: Grapsoidea: Gecarcinidae), and a description of

the megalop. Zoological Journal of the Linnean Society 146(2): 149–164. https://doi.org/10.1111/j.1096-3642.2006.00195.x

Hassall M, Rushton SP (1982) The role of coprophagy in the feeding strategies of terrestrial isopods. Oecologia 53(3): 374–381. https://doi.org/10.1007/BF00389017

Hassall M, Sutton SL (1978) The role of isopods as decomposers in a dune grassland ecosystem. Scientific Proceedings of the Royal Dublin Society. Series A 6: 235–245.

Hassall M, Turner JG, Rands MRW (1987) Effects of terrestrial isopods on the decomposition of woodland leaf litter. Oecologia 72(4): 597–604. https://doi.org/10.1007/BF00378988

Hegna TA, Lazo-Wasem EA (2010) *Branchinecta brushi* n. sp. (Branchiopoda: Anostraca: Branchinectidae) from a volcanic crater in northern Chile (Antofagasta Province): a new altitude record for crustaceans. Journal of Crustacean Biology 30(3): 445–464. https://doi.org/10.1651/09-3236.1

Henning HG (1975) Kampf-, fortpflanzungs- und hautungsverhalten-wachstum und geschlechtsreife von *Cardisoma guanhumi* Latreille (Crustacea, Brachyura). Forma et Functio 8: 463–510.

Herreid CF II (1963) Observations on the feeding behaviour of *Cardisoma guanhumi* (Latreille) in southern Florida. Crustaceana 5: 176–180. https://doi.org/10.1163/156854063X00093

Herreid CF II, Gifford CA (1963) The burrow habitat of the land crab, *Cardisoma guanhumi* (Latreille). Ecology 44(4): 773–775. https://doi.org/10.2307/1933027

Hicks J (1985) The breeding behaviour and migrations of the terrestrial crab *Gecarcoidea natalis* (Decapoda: Brachyura). Australian Journal of Zoology 33(2): 127–142. https://doi.org/10.1071/ZO9850127

Hicks J, Rumpff H, Yorkston H (1990) Christmas Crabs (2nd edn.). Christmas Island Natural History Association, Christmas Island.

Hill MP, O'Keeffe JH (1992) Some aspects of the ecology of the freshwater crab (*Potamonautes perlatus* Milne Edwards) in the upper reaches of the Buffalo River, Eastern Cape Province, South Africa. Southern African Journal of Aquatic Sciences 18(1–2): 42–50. https://doi.org/10.1080/10183469.1992.9631323

Hodge S, Standen V (2006) The use of 'cryptozoa boards' to examine the distribution of woodlice (Isopoda) and millipedes (Diplopoda) in a disused limestone quarry. Entomologist's Monthly Magazine 142: 55–61.

Hoese B (1981) Morphologie und Funktion des Wasserleitungssystems der terrestrischen Isopoden (Crustacea, Isopoda, Oniscoidea). Zoomorphology 98(2): 135–167. https://doi.org/10.1007/BF00310433

Hoese B (1982) Der *Ligia*-Typ des Wasserleitungssystems bei terrestrischen-Isopoden und seine Entwicklung in der Familie Ligiidae (Crustacea, Isopoda, Oniscoidea). Zoologische Jahrbucher. Abteilung fur Anatomie und Ontogenie der Tiere 108: 225–261.

Hoese B (1984) The marsupium in terrestrial isopods. Symposia of the Zoological Society of London 53: 65–76.

Hoese B, Janssen HH (1989) Morphological and physiological studies on the marsupium in terrestrial isopods. Monitore Zoologico Italiano. Nuova Seria Monografia 4: 153–173.

Holdich D (1984) The cuticular surface of woodlice: A search for receptors. Symposia of the Zoological Society of London 53: 9–48.

Holdich D, Lincoln R (1974) An investigation of the surface of the cuticle and associated sensory structures of the terrestrial isopod, Porcellio scaber. Journal of Zoology (Cambridge) 172(4): 469–482. https://doi.org/10.1111/j.1469-7998.1974.tb04379.x

Honek A, Martinkova Z, Saska P, Koprdova S (2009) Role of post-dispersal seed and seedling prédation in estabhshment of dandelion (*Taraxacum* agg.) plants. Agriculture, Ecosystems & Environment 134(1–2): 126–135. https://doi.org/10.1016/j.agee.2009.06.001

Horiguchi H, Hironaka M, Meyer-Rochow VB, Hariyama T (2007) Water uptake via two pairs of specialized legs in *Ligia exotica* (Crustacea, Isopoda). The Biological Bulletin 213(2): 196–203. https://doi.org/10.2307/25066635

Hornung E (2011) Evolutionary adaptation of oniscidean isopods to terrestrial life: structure, physiology and behavior. Terrestrial Arthropod Reviews 4: 95–130. https://doi.org/10.1163/187498311X576262

Hornung E, Szlavecz K, Dombos M (2015) Demography of some non-native isopods (Crustacea, Isopoda, Oniscidea) in a Mid-Atlantic forest, USA. ZooKeys 515: 127–143. https://doi.org/10.3897/zookeys.515.9403

Horwitz P (1990) A taxonomic revision of species in the freshwater crayfish genus *Engaeus* Erichson (Decapoda: Parastacidae). Invertebrate Taxonomy 4(3): 427–614. https://doi.org/10.1071/IT9900427

Horwitz P, Knott B (1991) The faunal assemblage in freshwater crayfish burrows in sedgeland and forest at Lightning Plains, western Tasmania. Papers and Proceedings of the Royal Society of Tasmania 125: 29–32. https://doi.org/10.26749/rstpp.125.29

How MJ, Pignatelli V, Temple SE, Marshall NJ, Hemmi JM (2012) High e-vector acuity in the polarisation vision system in the fiddler crab *Uca vomeris*. Journal of Experimental Biology 215: 2128–2134. https://doi.org/10.1242/jeb.068544

Hsu C-H, Otte ML, Liu C-C, Chou J-Y, Fang W-T (2018) What are the sympatric mechanisms for three species of terrestrial hermit crab (*Coenobita rugosus*, *C. brevimanus*, and *C. cavipes*) in coastal forests? PLoS ONE 13(12): e0207640. https://doi.org/10.1371/journal.pone.0207640

Huang C, Huang S-Z, Shen Z-X (2020) A New Long-legged Terrestrial Freshwater Crab, *Calcipotamon puglabrum* gen. nov. et sp. nov. (Crustacea: Decapoda: Potamidae), from Hainan Island, China. Zootaxa 4766(3): 447–456. https://doi.org/10.11646/zootaxa.4766.3.4

Hudec I, Fišer C, Dolanský J (2017) *Niphargus diadematus* sp. n. (Crustacea, Amphipoda, Niphargidae), an inhabitant of a shallow subterranean habitat in South Moravia (Czech Republic). Zootaxa 4291(1): 1–41. https://doi.org/10.11646/zootaxa.4291.1.3

Hughes LE, Ahyong ST (2016) Collecting and Processing Amphipods. Journal of Crustacean Biology 36(4): 584–588. https://doi.org/10.1163/1937240X-00002450

Hupało K, Grabowski M (2018) A first insight into the transatlantic population genetic structure of the beach flea, *Platorchestia platensis* (Krøyer, 1845). BioInvasions Records 7(2): 165–170. https://doi.org/10.3391/bir.2018.7.2.08

Hurley DE (1968) Transition from water to land in amphipod crustaceans. American Zoologist 8(3): 327–353. https://doi.org/10.1093/icb/8.3.327

Hutchinson GE (1957) A Treatise on Limnology (Vol. I). Geography, Physics, and Chemistry. New York. John Wiley and Sons, Inc., 1015 pp.

Huys R, Mackenzie-Dodds J, Llewellyn-Hughes J (2009) Cancrincolidae (Copepoda, Harpacticoida) associated with land crabs: A semiterrestrial leaf of the ameirid tree. Molecular Phylogenetics and Evolution 51(2): 143–156. https://doi.org/10.1016/j.ympev.2008.12.007

Ineson P, Anderson JM (1985) Aerobically isolated bacteria associated with the gut and faeces of the litter feeding macroarthropods *Oniscus asellus* and *Glomeris marginata*. Soil Biology & Biochemistry 17(6): 843–849. https://doi.org/10.1016/0038-0717(85)90145-2

Javidkar M, Cooper SJB, King RA, Humphreys WF, Austin AD (2015) Molecular phylogenetic analyses reveal a new southern hemisphere oniscidean family (Crustacea: Isopoda) with a unique water transport system. Invertebrate Systematics 29(6): e554. https://doi.org/10.1071/IS15010

Jazdzewski K, Konopacka A, Grabowski M (2004) Recent drastic changes in the gammarid fauna of the Vistula River deltaic system in Poland caused by alien invaders. Diversity and Distributions 10(2): 81–88. https://doi.org/10.1111/j. 1366–9516.2004.00062.x

Johnston K, Robson BJ (2009) Commensalism Used by Freshwater Crayfish Species to Survive Drying in Seasonal Habitats. Invertebrate Biology 128(3): 269–275. https://doi.org/10.1111/j.1744-7410.2009.00169.x

Johnston MD, Johnston DJ, Richardson AMM (2005) Digestive capabilities reflect the major food sources in three species of talitrid amphipods. Comparative Biochemistry and Physiology. B, Comparative Biochemistry 140(2): 251–257. https://doi.org/10.1016/j.cbpc.2004.10.007

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69(3): 373–386. https://doi.org/10.2307/3545850

Jordão JM, Cronin TW, Oliveira RF (2007) Spectral sensitivity of four species of fiddler crabs (*Uca pugnax*, *Uca pugilator*, *Uca vomeris* and *Uca tangeri*) measured by in situ microspectrophotometry. The Journal of Experimental Biology 210(3): 447–453. https://doi.org/10.1242/jeb.02658

Karagkouni M, Sfenthourakis S, Feldman A, Meiri S (2016a) Biogeography of body size in terrestrial isopods (Crustacea: Oniscidea). Journal of Zoological Systematics and Evolutionary Research 54(3): 182–188. https://doi.org/10.1111/jzs.12125

Karagkouni M, Sfenthourakis S, Meiri S (2016b) The island rule is not valid in terrestrial isopods (Crustacea: Oniscidea). Journal of Zoology 301(1): 11–16. https://doi.org/10.1111/jzo.12393

Karanovic I, Eberhard S, Perina G (2012) *Austromesocypris bluffensis* sp. n. (Crustacea, Ostracoda, Cypridoidea, Scottiinae) from subterranean aquatic habitats in Tasmania, with a key to world species of the subfamily. ZooKeys 215: 1–31. https://doi.org/10.3897/zookeys.215.2987

Kato M (1995) The aspidistra and the amphipod. Nature 377(6547): e293. https://doi.org/10.1038/377293a0

Katz LC (1980) Effects of burrowing by the fiddler crab, *Uca pugnax* (Smith). Estuarine and Coastal Marine Science 11(2): 233–237. https://doi.org/10.1016/S0302-3524(80)80043-0

Kautz G, Zimmer M, Topp W (2000) Responses of the parthenogenetic isopod, *Trichoniscus pusillus*, to changes in food quality. Pedobiologia 44: 75–85. https://doi.org/10.1078/S0031-4056(04)70029-3

Kellman M, Delfosse B (1993) Effect of the red land crab (*Gecarcinus lateralis*) on the leaf-litter in a tropical dry forest in Veracruz, Mexico. Journal of Tropical Ecology 9(1): 55–65. https://doi.org/10.1017/S0266467400006957

Kessler C (2005) Observation of a coconut crab, *Birgus latro* (Linnaeus, 1767) predation on a Polynesian rat, *Rattus exulans* (Peale, 1848). Crustaceana 78(6): 761–762. https://doi.org/10.1163/156854005774353485

Kight SL, Nevo M (2004) Female terrestrial isopods, *Porcellio laevis* Latreille (Isopoda: Oniscidea) reduce brooding duration and fecundity in response to physical stress. Journal of the Kansas. Entomological Society 77(3): 285–287. https://doi.org/10.2317/0307.09.1

Kikuchi Y (1984) Morphological comparison of two terrestrial species of *Moraria* (Canthocamptidae, Harpacticoida) from Japan, with the scanning electron microscope. Crustaceana 7(Supplement): 279–285.

Kingsbury BA (1996) Status of the eastern massasauga, *Sistrurus c. catenatus*, in Indiana with management recommendations for recovery. Proceedings of the Indiana Academy of Sciences 105: 195–205.

Kingsbury BA (1999) Status and ecology of three species of endangered reptile on the Pigeon River Fish and Wildlife Area and recommendations for management. Final report to the Indiana Department of Natural Resources, 114 pp.

Kingwill L (2008) The influence of land use on the species composition, burrow density and burrow activity of Engaeus (Parastacidae, Decapoda) in Gippsland, Victoria. Honours Thesis, Department of Zoology, La Trobe University, Melbourne, Australia.

Klaassen F (1975) Ecological and ethological studies on the reproductive biology of *Gecarcinus lateralis* (Decapoda, Brachyura). Forma Functio 8: 101–174.

Knaden M, Bisch-Knaden S, Linz J, Reinecke A, Krieger J, Erland S, Harzsch S, Hansson BS (2019) Acetoin, a key odor for resource location in the giant robber crab, *Birgus latro*. The Journal of Experimental Biology 222: jeb202929. https://doi.org/10.1242/jeb.202929

Koenemann S, Jenner RA, Hoenemann M, Stemme T, von Reumont BM (2010) Arthropod phylogeny revisited, with a focus on crustacean relationships. Arthropod Structure & Development 39: 88–110. https://doi.org/10.1016/j.asd.2009.10.003

Konopacka A, Grabowski M, Bqcela-Spychalska K, Rewicz T (2009) *Orchestia cavimana* Heller, 1865 (Amphipoda: Talitridae) enters freshwater inland habitats in the Vistula River, Poland. Aquatic Invasions 4(4): 689–691. https://doi.org/10.3391/ai.2009.4.4.16

Kozlovskaya LS, Striganova BR (1977) Food digestion and assimilation in desert woodlice and their relations to the soil microflora. Ecological Bulletins 25: 240–245.

Krång A-S, Knaden M, Steck K, Hansson BS (2012) Transition from sea to land: Olfactory function and constraints in the terrestrial hermit crab *Coenobita clypeatus*. Proceedings. Biological Sciences 279(1742): 3510–3519. https://doi.org/10.1098/rspb.2012.0596

Krieger J, Braun P, Rivera NT, Schubart CD, Müller CHG, Harzsch S (2015) Comparative analyses of olfactory systems in terrestrial crabs (Brachyura): Evidence for aerial olfaction? PeerJ 3: e1433. https://doi.org/10.7717/peerj.1433

Krieger J, Drew MM, Hansson BS, Harzsch S (2016) Notes on the foraging strategies of the Giant Robber Crab *Birgus latro* (Anomala) on Christmas Island: Evidence for active predation on red crabs *Gecarcoidea natalis* (Brachyura). Zoological Studies 55(6): 55–06.

Krieger J, Hörnig MK, Kenning M, Hansson BS, Harzsch S (2021) More than one way to smell ashore – Evolution of the olfactory pathway in terrestrial malacostracan crustaceans. Arthropod Structure & Development 60: e101022. https://doi.org/10.1016/j.asd.2020.101022

Kronauer DJC, Pierce NE (2011) Myrmecophiles. Current Biology 21(6): 208–209. https://doi.org/10.1016/j.cub.2011.01.050

Kuenen D, Nooteboom H (1963) Olfactory orientation in some land-isopods (Oniscoidea, Crustacea). Entomologia Experimentalis et Applicata 6(2): 133–142. https://doi.org/10.1111/j.1570-7458.1963.tb00610.x

Kuiters AT, Sarink HM (1986) Leaching of phenolic compounds from leaf and needle litter of several deciduous and coniferous trees. Soil Biology & Biochemistry 18(5): 475–480. https://doi.org/10.1016/0038-0717(86)90003-9

Kukor JJ, Martin MM (1986) The effects of acquired microbial enzymes on assimilation efficiency in the common woodlouse, *Tracheoniscus rathkei*. Oecologia 69: 360–366. https://doi.org/10.1007/BF00377057

Kuznetsova DM, Gongalsky KB (2012) Cartographic analysis of woodlice fauna of the former USSR. ZooKeys 176: 1–11. https://doi.org/10.3897/zookeys.176.2372

Lagerspetz KY, Vainio LA (2007) Thermal behaviour of crustaceans. Biological Reviews of the Cambridge Philosophical Society 81(02): 237–258. https://doi.org/10.1017/S1464793105006998

Lagidze OI, Levushkin S, Talikadze DA (1974) Pervyi vid obitayushchego v pochve bokoplava roda *Niphargus* (Amphipoda, Crustacea). Doklady Akademii Nauk SSSR 217(6): 1449–1452. [in Russian]

Laidre ME (2017) Ruler of the atoll: the world' largest land invertebrate. Frontiers in Ecology and the Environment 15(9): 527–528. https://doi.org/10.1002/fee.1730

Lake PS, O'Dowd DJ (1991) Red crabs in rain forest, Christmas Island: Biotic resistance to invasion by an exotic snail. Oikos 62(1): 25–29. https://doi.org/10.2307/3545442

Lardies M, Cotoras I, Bozinovic F (2004) The energetics of reproduction and parental care in the terrestrial isopod *Porcellio laevis*. Journal of Insect Physiology 50(12): 1127–1135. https://doi.org/10.1016/j.jinsphys.2004.10.005

Latreille PA (1802) Histoire naturelle, générale et particulière des Crustacés et des Insectes. Ouvrage faisant suite à l'histoire naturelle générale et particulière, composée par Leclerc de Buffon, et rédigée par C.S. Sonnini, membre de plusieurs Sociétés savantes (Vol. 3). Dufart, Paris, 476 pp. https://doi.org/10.5962/bhl.title.15764

Lavelle P, Bignell D, Lepage M, Wolters V, Roger P, Ineson P, Heal OW, Dhillion S (1997) Soil function in a changing world: The role of invertebrate ecosystem engineers. European Journal of Soil Biology 33: 159–193.

Lawton JH, Jones CG (1995) Linking species and ecosystems: organisms as ecosystem engineers. In: Jones CG, Lawton JH (Eds) Linking species and ecosystems. Chapman and Hall, New York, 141–150. https://doi.org/10.1007/978-1-4615-1773-3_14

Lazo-Wasem EA (1984) Physiological and behavioural ecology of the terrestrial amphipod *Arcitalitrus sylvaticus* (Haswell, 1880). Journal of Crustacean Biology 4(3): 343–355. https://doi.org/10.2307/1548035

Lee CM, Kwon TS (2015) Response of ground arthropods to effect of urbanization in southern Osaka, Japan. Journal of Asia-Pacific Biodiversity 8(4): 343–348. https://doi.org/10.1016/j.japb.2015.10.007

Lehman PS, Reid JW (1993) *Phyllognathopus viguieri* (Crustacea: Harpacticoida), a predaceous copepod of phytoparasitic, entomopathogenic, and free-living nematodes. Annual Proceedings Soil and Crop Science Society of Florida 52: 78–82.

Leijs R, Roudnew B, Mitchell J, Humphreys B (2009) A new method for sampling stygofauna from groundwater fed marshlands. Speleobiology Notes 1: 12–13.

Lenanton C, Alistar RA, Hansen JA (1982) Nearshore Accumulations of Detached Macrophytes as Nursery Areas for Fish. Marine Ecology Progress Series 9(1): 51–57. https://doi.org/10.3354/meps009051

Lim KKP (2013) Freshwater crab *Irmengardia johnsoni* eating caterpillar. Singapore Biodiversity Records 2013: 1–13.

Lincoln RJ (1979) British Marine Amphipoda: Gammaridea. British Museum (Natural History), London, 658 pp.

Lindquist ES, Carroll RC (2004) Differential seed and seedling predation by crabs: Impacts on tropical coastal forest composition. Oecologia 141(4): 661–667. https://doi.org/10.1007/s00442-004-1673-5

Lindquist ES, Krauss KW, Green PT, O'Dowd DJ, Sherman PM, Smith TJ III (2009) Land crabs as key drivers in tropical coastal forest recruitment. Biological Reviews of the Cambridge Philosophical Society 84(2): 203–223. https://doi.org/10.1111/j.1469-185X.2008.00070.x

Lindqvist OV (1968) Water regulation in terrestrial isopods, with comments on their behaviour in a stimulus gradient. Annales Zoologici Fennici 5: 279–311.

Linnaeus C (1758) Systema Naturae per Regna Tria Naturae, Secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis (Vol. 1). Editio decima, reformata [10th revised edition]. Laurentius Salvius, Holmiae, 824 pp. https://doi.org/10.5962/bhl.title.542

Linsenmair KE (1974) Some adaptations of the desert woodlouse *Hemilepistus reaumuri* (Isopoda, Oniscoidea) to desert environment. Sonderdruck: Verhandlungen der Gesellschaft fUr Ökologie 4: 183–185. https://doi.org/10.1007/978-94-017-4521-5_18

Linsenmair KE (1985) Individual and family recognition in subsocial arthropods, in particular in the desert isopod *Hemilepistus reaumuri*. Fortschritte der Zoologie 31: 411–436.

Linsenmair KE (1987) Kin recognition in subsocial arthropods, in particular in the desert isopod *Hemilepistus reaumuri*. Chapter 6. In: Fletcher DJC, Michener CD (Eds) Kin recognition in animals. John Wiley & Sons Ltd., NY, 465 pp.

Linsenmair KE (2008) Sociobiology of terrestrial isopods. In: Duffy JE, Thiel M (Eds) Evolutionary Ecology of Social and Sexual Systems – Crustaceans as Model Organisms. Oxford University Press, Oxford, 502 pp. https://doi.org/10.1093/acprof:oso/9780195179927.003.0016

Linton SM, Greenaway P (1997) Urate deposits in the Gecarcinid land crab, *Gecarcoidea natalis* are synthesised de novo from excess dietary nitrogen. The Journal of Experimental Zoology 200: 2347–2354. https://doi.org/10.1242/jeb.200.17.2347

Linton SM, Greenaway P (1998) Enzymes of urate synthesis and catabolism in the Gecarcinid land crab *Gecarcoidea natalis*. Experimental Biology Online 3(5): 1–5. https://doi.org/10.1007/s00898-998-0005-3

Linton SM, Greenaway P (2000) The nitrogen requirements and dietary nitrogen utilization for the gecarcinid land crab *Gecarcoidea natalis*. Physiological and Biochemical Zoology 73(2): 209–218. https://doi.org/10.1086/316735

Linton SM, Greenaway P (2004) Presence and properties of cellulase and hemicellulase enzymes of the gecarcinid land crabs *Gecarcoidea natalis* and *Discoplax hirtipes*. Journal of Experimental Biology 207: 4095–4104. https://doi.org/10.1242/jeb.01252

Linton S, Greenaway P (2007) A review of feeding and nutrition of herbivorous land crabs: Adaptations to low quality plant diets. Journal of Comparative Physiology. B, Biochemical, Systemic, and Environmental Physiology 177(3): 269–286. https://doi.org/10.1007/s00360-006-0138-z

Linton S, Wilde JE, Greenaway P (2005) Excretory and storage purines in the anomuran land crab *Birgus latro*: Guanine and uric acid. Journal of Crustacean Biology 25(1): 100–104. https://doi.org/10.1651/C-2515

Linton SM, Wright JC, Howe CG (2017) Nitrogenous waste metabolism within terrestrial crustacea, with special reference to purine deposits and their metabolism. In: Weihrauch D, O'Donnell M (Eds) Acid-base balance and nitrogen excretion in invertebrates. Springer, Cham, 25–59. https://doi.org/10.1007/978-3-319-39617-0_2

Little C (1983) The Colonisation of Land: Origins and Adaptations of Terrestrial Animals. Cambridge University Press, Cambridge, 300 pp.

Longo G, Trovato M, Mazzei V (2011) Variability of the female genital system morphology and of sperm storage in terrestrial isopods (Isopoda, Oniscidea). The Italian Journal of Zoology 78(3): 287–297. https://doi.org/10.1080/11250003.2010.544333

Lopez GR, Levinton JS, Slobodkin LB (1977) The effect of grazing by the detritivore *Orchestia grillus* on *Spurtina* litter and its associated microbial community. Oecologia 30(2): l1127. https://doi.org/10.1007/BF00345415

López-Victoria M, Werding B (2008) Ecology of the endemic land crab *Johngarthia malpilensis* (Decapoda: Brachyura: Gecarcinidae), a poorly known Species from the tropical Eastern Pacific. Pacific Science 62(4): 483–493. https://doi.org/10.2984/1534-6188(2008)62[483:EOTELC]2.0.CO;2

Louda SM, Zedler PH (1985). Predation in insular plant dynamics: an experimental assessment of postdispersal fruit and seed survival, Enewetak Atoll, Marshall Islands. American Journal of Botany 72: 438–445. https://doi.org/10.1002/j.1537-2197.1985.tb05367.x

Loughman ZJ (2010) Ecology of *Cambarus dubius* (Upland Burrowing Crayfish) in North–central West Virginia. Southeastern Naturalist 9(3): 217–230. https://doi.org/10.1656/058.009.s311

Loureiro S, Soares AMVM, Araújo PB, Sfenthourakis S, Hornung E, Zimmer M, Schmalfuss H, Taiti S [Eds] (2005) The Biology of Terrestrial Isopods, VI. European Journal of Soil Biology 41(3–4): 1–167.

Lowry JK, Coleman CO (2012) A new terrestrial talitrid genus from the Philippine Islands (Crustacea, Amphipoda, Talitrida, Talitridae) and the designation of two informal subgroups. Zootaxa 3400(1): 64–68. https://doi.org/10.11646/zootaxa.3400.1.5

Lowry JK, Myers AA (2019) New genera of Talitridae in the revised Superfamily Talitroidea Bulycheva 1957 (Crustacea, Amphipoda, Senticaudata). Zootaxa 4553(1): 1–100. https://doi.org/10.11646/zootaxa.4553.1.1

Lutz P (1969) Salt and water balance in the West African freshwater/land crab *Sudanonautes africanus africanus* and the effects of desiccation. Comparative Biochemistry and Physiology 30(3): 469–480. https://doi.org/10.1016/0010-406X(69)92016-7

Macfadyen A (1961) Improved funnel-type extractors for soil arthropods. Journal of Animal Ecology 30(1): 171–184. https://doi.org/10.2307/2120

MacMillen RE, Greenaway P (1978) Adjustments of energy and water metabolism to drought in an Australian arid-zone crab. Physiological Zoology 51(3): 230–240. https://doi.org/10.1086/physzool.51.3.30155740

Maitland DP (2003) Predation on Snakes by the Freshwater Land Crab *Eudaniela garmani*. Journal of Crustacean Biology 23(1): 241–246. https://doi.org/10.1163/20021975-99990331

Maple WT (1968) The overwintering adaptations of *Sistrurus catenatus catenatus* in northeastern Ohio. M. A. Thesis, Kent State Univ., OH, 64 pp.

Marin IN (2021) A new species of the genus *Potamalpheops* (Crustacea: Decapoda: Alpheidae) from the intertidal mangrove swamps of South Vietnam. Arthropoda Selecta 30(2): 179–191. https://doi.org/10.15298/arthsel.30.2.05

Marin IN, Palatov DM (2023) A new semi-terrestrial *Cryptorchestia* Lowry et Fanini, 2013 (Amphipoda: Talitridae) from the southwestern Caucasus and the Ciscaucasian Plain. Arthropoda Selecta 32(3).

Markwiese JT, Ryti RT, Hooten MM, Michael DI, Hlohowskyj I (2001) Toxicity bioassays for ecological risk assessment in arid and semiarid ecosystems. Reviews of Environmental Contamination and Toxicology 168: 43–98. https://doi.org/10.1007/978-1-4613-0143-1_2

Marsden ID (1991) Kelp-sandhopper interactions on a sand beach in New Zealand. II. Population dynamics of *Talorchestia quoyana* (Milne-Edwards). Journal of Experimental Marine Biology and Ecology 152(1): 75–90. https://doi.org/10.1016/0022-0981(91)90136-K

Martens K, Rossetti G, Horne DJ (2003) How ancient are ancient asexuals? Proceedings of the Royal Society B, Biological Sciences 270(1516): 723–729. https://doi.org/10.1098/rspb.2002.2270

Martens K, De Deckker P, Rossetti G (2004) On a new terrestrial genus and species of Scottiinae (Crustacea, Ostracoda) from Australia, with a discussion on the phylogeny and the zoogeography of the subfamily. Zoologischer Anzeiger 243(1–2): 21–36. https://doi.org/10.1016/j.jcz.2004.05.001

Martens K, Schön I, Meisch C, Horne DJ (2008) Global diversity of ostracods (Ostracoda, Crustacea) in freshwater. In: Balian E et al. (Eds) Freshwater Animal Diversity Assessment. Hydrobiologia 595: 185–193. https://doi.org/10.1007/s10750-007-9245-4

Mathieu J, Essafi-Chergui K, Jeannerod F (1994) A gradient of interstitial *Niphargus rhenorhodanensis* populations in two karst-floodplain transition zones of the French Jura. Hydrobiologia 286(3): 129–137. https://doi.org/10.1007/BF00006244

Maynard ME, Oxenford HA (2014) Characterisation of the commercial mangrove land crab fishery in Trinidad. https://www.cavehill.uwi.edu/cermes/getdoc/456a033f–c5b8–4153–a08a–078b1073dde7/maynard_oxenford_2014_trinidad_land_crab_fishery_c.aspx [Accessed 10 July 2017]

McCann C (1938) Notes on the common land crab *Paratelphusa* (*Barytelphusa*) *guerini* of Salsette Island. Journal of the Bombay Natural History Society 39: 531–542.

McCormack RB, Raadik TA (2021) *Cherax latimanus* sp. nov., a new burrow-dwelling freshwater crayfish (Decapoda, Parastacidae) from the mid-Murray River catchment, Australia. Zootaxa 5026(3): 344–374. https://doi.org/10.11646/zootaxa.5026.3.2

McMahon BR, Burggren WW (1988) Respiration. In: Burggren WW, McMahon BR (Eds) Biology of the land crabs. Cambridge University Press, Cambridge, 249–297. https://doi.org/10.1017/CBO9780511753428.009

Menzel R (1916) Über das Auftreten der Harpacticidengattung *Epactophanes* Mrázek und *Parastenocaris* Kessler in Surinam. Zoologischer Anzeiger 47: 145–152.

Menzel R (1921) Beitrage zur Kenntnis der Mikrofauna von Niederlan- disch Ost-Indien. I. Moosbewohnende Harpactkiden. Treubia 2: 137–145.

Menzel R (1923) Beitrage zur Kenntnis der Mikrofauna von Nieder- landisch-Ostindien. 111. Harpacticiden als Bromeliaceenbe wohner. Treubia 3: 122–126.

Menzel R (1926) Cyclopides muscicoles et bromélicoles de Java (Indes Néerlandaises). Annales de Biologie Lacustre14: 209–216.

Messelink GJ, Bloemhard CMJ (2007) Woodlice (Isopoda) and millipedes (Diplopoda): Control of rare greenhouse pests. Proceedings of the Section Experimental and Applied EntomologyNetherlands Entomological Society 18: 43–49.

Micheli F, Gherardi M, Vannini M (1991) Feeding and burrow ecology of two East African mangrove crabs. Marine Biology 111(2): 247–254. https://doi.org/10.1007/BF01319706

Mocquard JP, Juchault P, Jambu P, Fustec E (1988) Essai d'évaluation du rôle des crustacés oniscoïdes dans la transformation des matières végétales dans une forêt feuillue de l'ouest de la France. Revue d'Ecologie et de Biologie du Sol 24(3): 311–327.

Montagu G (1808) Supplement to Testacea Britannica with Additional Plates. Woolmer, Exeter, 183 pp.

Montague CL (1980) A natural history of temperate western Atlantic fiddler crabs (genus *Uca*) with reference to their impact on the salt marsh. Contributions in Marine Science 23: 25–55.

Montague CL (1982) The influence of fiddler crab burrows and burrowing on metabolic processes in salt marsh sediments. In: Kennedy VS (Ed.) Estuarine Comparisons. Academic Press, Oregon, 283–301. https://doi.org/10.1016/B978-0-12-404070-0.50023-5

Moore PG, Francis CH (1985) On the water relations and osmoregulation of the beach-hopper *Orchestia gammarellus* (Pallas) (Crustacea: Amphipoda). Journal of Experimental Marine Biology and Ecology 94: 131–150. https://doi.org/10.1016/0022-0981(85)90054-1

Moore PG, Francis CH (1986a) Notes on the breeding periodicity and sex ratio of *Orchestia gammarellus* at Millport, Scotland. Journal of Experimental Marine Biology and Ecology 95: 203–210. https://doi.org/10.1016/0022-0981(86)90253-4

Moore PG, Francis CH (1986b) Environmental tolerances of the beach-hopper *Orchestia gammarellus* (Pallas) (Crustacea: Amphipoda). Marine Environmental Research 19(2): 115–129. https://doi.org/10.1016/0141-1136(86)90042-5

Moore ML, Richardson AMM (1992) Water uptake and loss via the urosome in terrestrial talitrid amphipods (Crustacea: Amphipoda). Journal of Natural History 26(1): 67–78. https://doi.org/10.1080/00222939200770041

Moore PG, Taylor AC (1984) Gill area relationships in an ecological series of gammaridean amphipods (Crustacea). Journal of Experimental Marine Biology and Ecology 74(2): 179–186. https://doi.org/10.1016/0022-0981(84)90085-6

Moore PG, MacAlister HE, Taylor AC (1995) The environmental tolerances and behavioural ecology of the subAntarctic beach-hopper '*Orchestia*' *scutigulera* Dana (Crustacea: Amphipoda) from Husvik, South Georgia. Journal of Experimental Marine Biology and Ecology 189(1–2): 159–182. https://doi.org/10.1016/0022-0981(95)00022-J

Morris S (2002) The ecophysiology of air-breathing in crabs with special reference to *Gecarcoidea natalis*. Comparative Biochemistry and Physiology Part B 131(4): 559–570. https://doi.org/10.1016/S1096-4959(02)00011-8

Morris S (2005) Respiratory and acid-base responses during migration and to exercise by the terrestrial crab *Discoplax* (*Cardisoma*) *hirtipes*, with regard to season, humidity and behavior. The Journal of Experimental Biology 208(22): 4333–4343. https://doi.org/10.1242/jeb.01918

Morris S, Dela-Cruz J (1998) The ecophysiological significance of lung air retention during submersion by the air-breathing crabs *Cardisoma carnifex* and *Cardisoma hirtipes*. Experimental Biology Online 3(10): 1–15. https://doi.org/10.1007/s00898-998-0010-6

Morrison LW, Spiller DA (2006) Land hermit crab (*Coenobita clypeatus*) densities and patterns of gastropod shell use on small Bahamian islands. Journal of Biogeography 33(2): 314–322. https://doi.org/10.1111/j.1365-2699.2005.01399.x

Morritt D (1987) Evaporative water loss under desiccation stress in semiterrestrial and terrestrial amphipods (Crustacea: Amphipoda: Talitridae). Journal of Experimental Marine Biology and Ecology 111(2): 145–157. https://doi.org/10.1016/0022-0981(87)90052-9

Morritt D (1998) Hygrokinetic responses of talitrid amphipods. Journal of Crustacean Biology 18(1): 25–35. https://doi.org/10.2307/1549517

Morritt D (1998) Hygrokinetic responses of talitrid amphipods. Journal of Crustacean Biology 18(1): 25–35. https://doi.org/10.2307/1549517

Morritt D, Richardson AMM (1998) Female control of the embryonic environment in a terrestrial amphipod, *Mysticotalitrus cryptus* (Crustacea). Functional Ecology 12(3): 351–358. https://doi.org/10.1046/j.1365-2435.1998.00196.x

Morritt D, Spicer JI (1998) The physiological ecology of talitrid amphipods: An update. Canadian Journal of Zoology 76(11): 1965–1982. https://doi.org/10.1139/z98-168

Myers A, Lowry J (2020) A phylogeny and classification of the Talitroidea (Amphipoda, Senticaudata) based on interpretation of morphological synapomorphies and homoplasies. Zootaxa 4778(2): 281–310. https://doi.org/10.11646/zootaxa.4778.2.3

Neuhauser EF, Hartenstein R (1976) Degradation of phenol, cinnamic and quinic acid in the terrestrial crustacean, *Oniscus asellus*. Soil Biology & Biochemistry 8(2): 95–98. https://doi.org/10.1016/0038-0717(76)90071-7

Ng PKL (1988) The Freshwater Crabs of Peninsular Malaysia and Singapore. Department of Zoology, National University ofSingapore, Shinglee Press, Singapore, 156 pp.

Ng PKL (1989) *Parathelphusa maculata*, the common Lowland Freshwater Crab of Peninsular Malaysia and Singapore. Nature Malaysiana 14: 130–135.

Ng PKL (1991) Bornean freshwater crabs of the genus *Arachnothelphusa* gen. nov. (Crustacea: Decapoda: Brachyura: Gecarcinucidae). Zoölogische Mededeelingen 65: 1–12.

Ng PKL (1995) *Ceylonthelphusa scansor*, a new species of tree-climbing crab from Sinharaja Forest in Sri Lanka (Crustacea: Decapoda: Brachyura: Parathelphusidae). Journal of South Asian Natural History 1: 175–184.

Ng PKL (2017) On the Identities of The Highland Vamire Crabs, *Geosesarma foxi* (Kemp, 1918) and *G. serenei* Ng, 1986, with Description of A New Phytotelmic Species from Penang, Peninsular Malaysia (Crustacea: Decapoda: Brachyura: Sesarmidae). Raffles of Zoology 65: 226–242.

Ng PKL, Lim RP (1987) The taxonomy and biology of the nepenthiphilous sesarmine freshwater crab, *Geosesarma malayanum* Ng and Lim, 1986 (Crustacea, Decapoda, Brachyura, Grapsidae) from Peninsular Malaysia. Malayan Nature Journal 41(2–3): 393–402.

Ng PKL, Liu H-C (2003) On a new species of tree-climbing crab of the genus *Labuanium* (Crustacea: Decapoda: Brachyura: Sesarmidae) from Taiwan. Proceedings of the Biological Society of Washington 116: 601–616.

Ng PKL, Ng PYC (2018) The freshwater crabs of Danum Valley Conservation Area in Sabah, East Malaysia, with a description of a new species of *Thelphusula* Bott, 1969 (Crustacea, Brachyura, Gecarcinucidae, Potamidae, Sesarmidae). ZooKeys 760(2): 89–112. https://doi.org/10.3897/zookeys.760.24787

Ng PYC, Ng PKL (2019) *Geosesarma spectrum*, a new species of semiterrestrial vampire crab (Crustacea: Decapoda: Brachyura: Sesarmidae) from Brunei Darussalam, Borneo. Zootaxa 4614(3): 529–540. https://doi.org/10.11646/zootaxa.4614.3.6

Ng PKL, Tan CGS (1995) *Geosesarma notophorum* sp. nov. (Decapoda, Brachyura, Grapsidae, Sesarminae), a terrestrial crab from Sumatra, with novel brooding behaviour. Crustaceana 68(8): 390–395. https://doi.org/10.1163/156854095X01493

Ng DJJ, Yeo DCJ (2013) Terrestrial scavenging behaviour of the Singapore freshwater crab, *Johora singaporensis* (Crustacea: Brachyura: Potamidae). Nature in Singapore 6: 207–210.

Ng PKL, Guinot D, Davie PJF (2008) Systema Brachyurorum: Part I. An annotated checklist of extant brachuyuran crabs of the world. The Raffles Bulletin of Zoology 17: 1–286.

Ng PKL, Lee BY, Tan HH (2015a) Notes on the Taxonomy and Ecology of *Labuanium politum* (De Man, 1887) (Crustacea: Decapoda: Sesarmidae), An Obligate Arboreal Crab on the Nipah Palm, *Nypa fruticans* (Arecales: Arecaceae). The Raffles Bulletin of Zoology (Supplement 31): 216–225.

Ng PKL, Schubart CD, Lukhaup C (2015b) New species of "Vampire Crabs" (*Geosesarma* De Man, 1892) from central Java, Indonesia, and the identity of *Sesarma* (*Geosesarma*) *nodulifera* De Man, 1892 (Crustacea, Brachyura, Thoracotremata, Sesarmidae). The Raffles Bulletin of Zoology 63: 3–13.

Niering WA (1956) Bioecology of Kapingamarangi, Caroline Islands: Terrestrial aspects. Atoll Research Bulletin 49: 1–32. https://doi.org/10.5479/si.00775630.49.1

Niering WA (1963) Terrestrial ecology of Kapingamarangi Atoll, Caroline Islands. Ecological Monographs 33(2): 131–160. https://doi.org/10.2307/1948559

Nihei SS (2016) Family Rhinophoridae. Zootaxa 4122(1): 881–883. https://doi.org/10.11646/zootaxa.4122.1.74

Norrocky MJ (1984) Burrowing crayfish trap. Ohio Journal of Science 84: 65–66.

Norrocky MJ (1991) Observations on the ecology, reproduction and growth of the burrowing crayfish *Fallicambarus* (*Creaserinus*) *fodiens* (Decapoda, Cambaridae) in northcentral Ohio. American Midland Naturalist 125(1): 75–86. https://doi.org/10.2307/2426371

O'Donnell MJ, Wright JC (1995) Nitrogen excretion in terrestrial crustaceans. In: Walsh PJ, Wright P (Eds) Nitrogen Metabolism and Excretion. CRC Press, Boca Raton, 105–118.

O'Dowd DJ, Lake PS (1989) Red crabs in rain forest, Christmas Island: Removal and relocation of leaf rail. Journal of Tropical Ecology 5(3): 337–348. https://doi.org/10.1017/S0266467400003746

O'Dowd DJ, Lake PS (1990) Red crabs in rain forest, Christmas Island: differential herbivory of seedlings. Oikos 58: 289–292. https://doi.org/10.2307/3545219

O'Dowd DJ, Lake PS (1991) Red crabs in rain forest, Christmas Island: Removal and fate of fruits and seeds. Journal of Tropical Ecology 7(1): 113–122. https://doi.org/10.1017/S0266467400005162

O'Dowd DJ, Green PT, Lake PS (2003) Invasional 'meltdown' on an oceanic island. Ecology Letters 6(9): 812–817. https://doi.org/10.1046/j.1461-0248.2003.00512.x

O'Hanlon RP, Bolger T (1999) The importance of *Arcitalitrus dorrieni* (Hunt) (Crustacea, Amphipoda: Talitridae) in coniferous litter breakdown. Applied Soil Ecology 11(1): 29–33. https://doi.org/10.1016/S0929-1393(98)00134-6

Odum HT, Abbott W, Selander RK, Golley FB, Wilson RF (1970) Estimates of chlorophyll and biomass of the Tobonuco Forest of Puerto Rico. In: Odum HT, Pigeon RF (Eds) A Tropical Rain Forest: a study of irradiation and ecology at El Verde, Puerto Rico, U.S. Atomic Energy Commission, Washington, 3–18.

Ott D, Rall BC, Brose U (2012) Climate change effects on macrofaunal litter decomposition: The interplay of temperature, body masses and stoichiometry. Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences 367(1605): 3025–3032. https://doi.org/10.1098/rstb.2012.0240

Page HM, Willason SW (1982) Distribution patterns of terrestrial hermit crabs at Enewetak Atoll, Marshall Islands. Pacific Science 36: 107–117.

Page HM, Willason SW (1983) Feeding Activity Patterns and Carrion Removal by Terrestrial Hermit Crabs at Enewetak Atoll, Marshall Islands. Pacific Science 37(2): 151–155.

Palatov DM, Marin IN (2020) A new genus of the family Crangonyctidae (Crustacea, Amphipoda) from the Palaearctic, with descriptions of two new species from the foothills of the Altai mountains. Zoologicheskij Zhurnal 99(10): 1160–1186. https://doi.org/10.31857/S004451342010013X

Paoletti MG, Hassall M (1999) Woodlice (Isopoda: Oniscidea): their potential for assessing sustainability and use as bioindicators. Agriculture, Ecosystems & Environment 74(1–3): 157–165. https://doi.org/10.1016/S0167-8809(99)00035-3

Paoletti MG, Stinner BR, Stinner D, Benzing D, Taylor R (1991) Diversity of soil fauna in the canopy of neotropical rain forest. Journal of Tropical Ecology 7: 373–383. https://doi.org/10.1017/S0266467400005654

Paoletti MG, Tsitsilas A, Thomson LJ, Taiti S, Umina PA (2008) The flood bug, *Australiodillo bifrons* (Isopoda: Armadillidae): A potential pest of cereals in Australia? Applied Soil Ecology 39(1): 76–83. https://doi.org/10.1016/j.apsoil.2007.11.009

Paoli P, Ferrara F, Taiti S (2002) Morphology and evolution of the respiratory apparatus in the family Eubelidae (Crustacea, Isopoda, Oniscidea). Journal of Morphology 253(3): 272–289. https://doi.org/10.1002/jmor.10008

Pape T, Arnaud Jr PH (2001) *Bezzimyia* – a genus of native New World Rhinophoridae (Insecta, Diptera). Zoologica Scripta 30(4): 257–297. https://doi.org/10.1046/j.1463-6409.2001.00064.x

Parmentier T, Vanderheyden A, Dekoninck W, Wenseleers W (2017) Body size in the ant–associated arthropod *Platyarthrus hoffmannseggii* is host-dependent. Biological Journal of the Linnean Society. Linnean Society of London 121(2): 305–311. https://doi.org/10.1093/biolinnean/blw052

Paulay G, Starmer J (2011) Evolution, Insular Restriction, and Extinction of Oceanic Land Crabs, Exemplified by the Loss of an Endemic *Geograpsus* in the Hawaiian Islands. PLoS ONE 6(5): e19916. https://doi.org/10.1371/journal.pone.0019916

Pekár S, Toft S (2015) Trophic specialisation in a predatory group: The case of prey–specialised spiders (Araneae). Biological Reviews of the Cambridge Philosophical Society 90(3): 744–761. https://doi.org/10.1111/brv.12133

Pekár S, Líznarová E, Řezáč M (2016) Suitability of woodlice prey for generalist and specialist spider predators: A comparative study. Ecological Entomology 41(2): 123–130. https://doi.org/10.1111/een.12285

Pérez-Chi A (2005) Densities, diel activity, burrow shape, and habitat characteristics of *Gecarcinus* (*Johngarthia*) *planatus* Stimpson, 1860 (Decapoda, Brachyura, Gecarcinidae) at Socorro Island, Revillagigedo, Mexico. Crustaceana 78(3): 255–272. https://doi.org/10.1163/1568540054286510

Perger R (2014) The land crab *Johngarthia planata* (Stimpson, 1860) (Crustacea, Brachyura, Gecarcinidae) colonizes human-dominated ecosystems in the continental mainland coast of Mexico. Biodiversity Data Journal 2: e1161. https://doi.org/10.3897/BDJ.2.e1161

Perger R, Cortes J, Pacheco C (2013) Closing a distributional gap of over 3000 km and encountering an invisible barrier: New presence/absence data for *Johngarthia planata* Stimpson, 1860 (Decapoda, Brachyura, Gecarcinidae) for Central America and biogeographic notes on East Pacific Gecarcinidae. Crustaceana 86(3): 268–277. https://doi.org/10.1163/15685403-00003172

Perneta JC (1976) Diets of the shrews *Sorex araneus* L. and *Sorex minutus* L. in Wytham grassland. Journal of Animal Ecology 45(3): 899–912. https://doi.org/10.2307/3588

Perttunen V (1961) Reactions de *Ligia italica* F. a la lumiere et a l'humidite de l'air. Vie et Milieu 12(2): 219–259.

Pfannkuche O, Thiel H (1988) Sample Processing. In: Higgins RP, Thiel H (Eds) Introduction to the Study of Meiofauna. Smithsonian Institute Press, Washington DC, 134–145.

Philpott SM, Cotton J, Bichier P, Friedrich RL, Moorhead LC, Uno S, Valdez M (2014) Local and landscape drivers of arthropod abundance, richness, and trophic composition in urban habitats. Urban Ecosystems 17(2): 513–532. https://doi.org/10.1007/s11252-013-0333-0

Ping X, Lee JS, Garlick D, Jiang Z, Blaisdell AP (2015) Behavioral evidence illuminating the visual abilities of the terrestrial Caribbean hermit crab *Coenobita clypeatus*. Behavioural Processes 118: 47–58. https://doi.org/10.1016/j.beproc.2015.06.003

Pinheiro MAA, Fiscarelli AG, Hattori GY (2005) Growth of the mangrove crab *Ucides cordatus* (Brachyura, Ocypodidae). Journal of Crustacean Biology 25(2): 293–301. https://doi.org/10.1651/C-2438

Pinto RL, Rocha CEF, Martens K (2004) On the genus *Penthesilenula* Rossetti and Martens, (Crustacea, Ostracoda, Darwinulidae) from (semi-) terrestrial habitats in São Paulo State (Brazil), with the description of a new species. Journal of Natural History 38(20): 2567–2589. https://doi.org/10.1080/00222930310001647424

Pinto RL, Rocha CEF, Martens K (2005a) On new terrestrial ostracods (Crustacea, Ostracoda) from Brazil, primarily from São Paulo State. Zoological Journal of the Linnean Society 145(2): 145–173. https://doi.org/10.1111/j.1096-3642.2005.00185.x

Pinto RL, Rocha CEF, Martens K (2005b) On new terrestrial ostracods (Crustacea, Ostracoda) from Brazil, primarily from São Paulo State. Zoological Journal of the Linnean Society 145(2): 145–173. https://doi.org/10.1111/j.1096-3642.2005.00185.x

Pinto RL, Rocha CEF, Martens K (2008) On the first terrestrial ostracod of the Superfamily Cytheroidea (Crustacea, Ostracoda): Description of *Intrepidocythere ibipora* n. gen. n. sp. from forest leaf litter in São Paulo State, Brazil. Zootaxa 1828(1): 29–42. https://doi.org/10.11646/zootaxa.1828.1.3

Plowman KP (2006) Litter and soil fauna of two Australian subtropical soils. Austral Ecology 4(1): 87–104. https://doi.org/10.1111/j.1442-9993.1979.tb01200.x

Poinsot-Balaguer N, Racon L, Sadaka N, Le Petit J (1993) Effects of tannin compounds on two species of Collembola. European Journal of Soil Biology 29: 13–16.

Polanska MA, Kirchhoff T, Dircksen H, Hansson BS, Harzsch S (2020) Functional morphology of the primary olfactory centers in the brain of the hermit crab *Coenobita clypeatus* (Anomala, Coenobitidae). Cell and Tissue Research 380(3): 449–467. https://doi.org/10.1007/s00441-020-03199-5

Pollard SD, Jackson RR, van Olphen A, Robertson MV (1995) Does *Dysdera crocata* (Araneae Dysderidae) prefer woodlice as prey? Ethology Ecology and Evolution 7(3): 271–275. https://doi.org/10.1080/08927014.1995.9522957

Poore GC, Bruce NL (2012) Global diversity of marine isopods (except Asellota and crustacean symbionts). PLoS ONE 7(8): e43529. https://doi.org/10.1371/journal.pone.0043529

Potapov AM, Beaulieu F, Birkhofer K, Bluhm SL, Degtyarev MI, Devetter M, Goncharov AA, Gongalsky KB, Klarner B, Korobushkin DI, Liebke DF, Maraun M, Mc Donnell RJ, Pollierer MM, Schaefer I, Shrubovych J, Semenyuk EI, Sendra A, Tuma G, Scheu S (2022) Feeding habits and multifunctional classification of soil-associated consumers from protists to vertebrates. Biological Reviews 97(3): 1057–1117. https://doi.org/10.1111/brv.12832

Powers LW, Bliss DE (1983) Terrestrial adaptations. In: Vernberg FJ, Vernberg WB (Eds) The Biology of Crustacea 8, Environmental Adaptations. Academic Press, London, 271–333.

Provenzano AJ (1983) The Biology of Crustacea, 6. Pathobiology. Academic Press, NY, 290 pp.

Pugh PJA, Dartnall HJG, McInnes S (2002) The non-marine Crustacea of Antarctica and the Islands of the Southern Ocean: Biodiversity and biogeography. Journal of Natural History 36(9): 1047–1103. https://doi.org/10.1080/00222930110039602

Quadros AF, Araujo PB (2008) An assemblage of terrestrial isopods (Crustacea) in Southern Brazil and their contribution to leaf litter processing. Revista Brasileira de Zoologia 25(1): 58–66. https://doi.org/10.1590/S0101-81752008000100009

Quensen III JF, Woodruff DS (1997) Associations between shell morphology and land crab predation in the land snail *Cerion*. Functional Ecology 11(4): 464–471. https://doi.org/10.1046/j.1365-2435.1997.00115.x

Rahayu LD, Shih H-T, Ng PKL (2016) A new species of land hermit crab in the genus *Coenobita* Latreille, 1829 from Singapore, Malaysia and Indonesia, previously confused with *C. cavipes* Stimpson, 1858 (Crustacea: Decapoda: Anomura: Coenobitidae). The Raffles Bulletin of Zoology (Supplement 34): 470–488.

Rana S (2018) Ethno-medicinal importance of crabs. International Journal of Zoology Studies 3(4): 06–07.

Regier JC, Shultz JW, Zwick A, Hussey A, Ball B, Wetzer R, Martin JW, Cunningham CW (2010) Arthropod relationships revealed by phylogenomic analysis of nuclear protein-coding sequences. Nature 463(7284): 1079–1083. https://doi.org/10.1038/nature08742

Reid JW (1982) *Forficatocaris schadeni*, a new copepod (Harpacticoida) from central Brazil, with keys to the species of the genus. Journal of Crustacean Biology 2(4): 578–587. https://doi.org/10.2307/1548098

Reid JW (1986) Some usually overlooked cryptic copepod habitats. Proceedings of the Second International Conference on Copepoda, Ottawa, Canada, 13– 17 August 1984. Syllogeus 58: 594–598.

Reid JW (1993) The harpacticoid and cyclopoid copepod fauna in the cerrado region of central Brazil. 1. Species composition, habitats, and zoogeography. Acta Limnologica Brasiliensia 6: 56–68.

Reid JW (2001) A human challenge: Discovering and understanding continental copepod habitats. Hydrobiologie 453/454: 201–226. https://doi.org/10.1023/A:1013148808110

Reid JW, Rocha CEF (2003) *Pindamoraria boraceiae*, a new genus and species of freshwater Canthocamptidae (Copepoda, Harpacticoida) from Brazil. Zoological Journal of the Linnean Society 139(1): 81–92. https://doi.org/10.1046/j.1096-3642.2003.00068.x

Reynolds J, Souty-Grosset C, Richardson A (2013) Ecological roles of crayfish in freshwater and terrestrial habitats. Freshwater Crayfish 19(2): 197–218.

Rezáč M, Pekár S (2007) Evidence for woodlice-specialization in *Dysdera* spiders: Behavioral versus developmental approaches. Physiological Entomology 32(4): 367–371. https://doi.org/10.1111/j.1365-3032.2007.00588.x

Rezáč M, Pekár S, Lubin Y (2008) How oniscophagous spiders overcome woodlouse armour. Journal of Zoology 275(1): 64–71. https://doi.org/10.1111/j.1469-7998.2007.00408.x

Richardson AMM (1980) Notes on the occurrence of *Talitrus dorrieni* Hunt (Crustacea; Amphipoda: Talitridae) in south-west England. Journal of Natural History 14(6): 751–757. https://doi.org/10.1080/00222938000770641

Richardson AMM (1983) The effect of the burrows of a crayfish on the respiration of the surrounding soil. Soil Biology & Biochemistry 15(3): 239–242. https://doi.org/10.1016/0038-0717(83)90065-2

Richardson AMM (1992) Altitudinal distribution of native and alien landhoppers (Amphipoda: Talitridae) in the Ko'olau range, O'ahu, Hawaiian Islands. Journal of Natural History 26(2): 339–352. https://doi.org/10.1080/00222939200770181

Richardson AMM (1998) Gill morphology in a functional series of talitrid amphipod crustaceans. Australian Biologist 11(1): 1–8.

Richardson AAM, Araujo PB (2015) Lifestyles of terrestrial crustaceans. The natural history of the Crustacea. Lifestyles and feeding biology: 299–336.

Richardson AMM, Jackson JE (1995) The first record of a terrestrial landhopper (Crustacea: Amphipoda: Talitridae) from Macquarie Island. Polar Biology 15(6): 419–422. https://doi.org/10.1007/BF00239718

Richardson AAM, Morton HP (1986) Terrestrial amphipods (Crustacea, Amphipoda, F. Talitridae) and soil respiration. Soil Biology & Biochemistry 18(2): 197–200. https://doi.org/10.1016/0038-0717(86)90027-1

Richardson AMM, Swain R (1990) Pattern and persistence in the burrows of two species of the freshwater crayfish *Parastacoides* (Decapoda: Parastacidae) in southwest Tasmania. Memoirs of the Queensland Museum 31: e283.

Richardson AMM, Swain R (2000) Terrestrial evolution in Crustacea: The talitrid amphipod model. Crustacean Issues 12: 807–816.

Richardson AMM, Chester ET, Swain R (2001a) Brood plate morphology and its implications for brooding in an ecological series of talitrid amphipods. Polskie Archiwum Hydrobiologii 48(3–4): 631–642.

Richardson AMM, Swain R, McCoull C (2001b) Salt spray limits the inland penetration of a coastally restricted invertebrate: a field experiment using landhoppers (Crustacea: Amphipoda: Talitridae). Functional Ecology 15(4): 435–442. https://doi.org/10.1046/j.0269-8463.2001.00545.x

Richardson AMM, Swain R, McCoull C (2003) What limits the distributions of coastally restricted terrestrial invertebrates? The case of coastal landhoppers (Crustacea: Amphipoda: Talitridae) in southern Tasmania. Journal of Biogeography 30(5): 687–695. https://doi.org/10.1046/j.1365-2699.2003.00850.x

Ridge J, Simon TP, Karns D, Robb J (2008) Comparison of three burrowing crayfish capture methods based on relationships with species morphology, seasonality, and habitat quality. Journal of Crustacean Biology 28(3): 466–472. https://doi.org/10.1651/07-2886R.1

Rigaud T, Moreau J (2004) A cost of *Wolbachia*-induced sex reversal and female-biased sex ratios: Decrease in female fertility after sperm depletion in a terrestrial isopod. Proceedings of the Royal Society B, Biological Sciences 271(1551): 1941–1946. https://doi.org/10.1098/rspb.2004.2804

Rittschof D, Sutherland JP (1986) Field studies on chemically mediated behavior in land hermit crabs: Volatile and nonvolatile odors. Journal of Chemical Ecology 12(6): 1273–1284. https://doi.org/10.1007/BF01012347

Robinson DA, Campbell CS, Hopmans JW, Hornbuckle BK, Jones SB, Knight R, Ogden F, Selker J, Wendroth O (2008) Soil Moisture Measurement for Ecological and Hydrological Watershed–Scale Observatories: A Review. Vadose Zone Journal 7(1): 358–389. https://doi.org/10.2136/vzj2007.0143

Rocha CEF, Bjornberg MHGC (1988) *Allocyclops silvaticus* sp. n. (Copepoda, Cyclopoida, Cyclopidae), the first representative of the genus in South America. Hydrobiologia 167/168(1): 445–448. https://doi.org/10.1007/BF00026337

Rota-Stabelli O, Kayal E, Gleeson D, Daub J, Boore J, Telford MJ, Pisani D, Blaxter M, Lavrov DV (2010) Ecdysozoan mitogenomics: Evidence for a common origin of the legged invertebrates, the Panarthropoda. Genome Biology and Evolution 2: 425–440. https://doi.org/10.1093/gbe/evq030

Rumpff H (1986) Ethology, Ecology and Population Biology Field Studies of the Coconut Crab, *Birgus latro* L. (Paguridea, Crustacea, Decapoda), on Christmas Island (Indian Ocean). PhD thesis, Westfaelische Wilhelms-Universitaet, Muenster, Germany.

Rudolph EH, Crandall K (2012) A new species of burrowing crayfish, *Virilastacus jarai* (Crustacea, Decapoda, Parastacidae) from central–southern Chile. Source: Pro-

ceedings of the Biological Society of Washington 125(3): 258–275. https://doi.org/10.2988/11-39.1

Rushton SP, Hassall M (1983) Food and feeding rates of the terrestrial isopod *Armadillidium vulgare* (Latreille). Oecologia 57(3): 415–419. https://doi.org/10.1007/BF00377189

Saska P (2008) Granivory in terrestrial isopods. Ecological Entomology 33: 742–747. https://doi.org/10.1111/j.1365-2311.2008.01026.x

Schaefer M, Schauermann J (1990) The soil fauna of beech forests: Comparison between a mull and a moder soil. Pedobiologia 34: 299–314.

Schliebe U (1988) Aggregation bei terrestrischen Isopoden. Mitteilungen der Deutschen Gesellschaft fur Allgemeine und Angewandte Entomologie 6: 70–75.

Schmalfuss H (1978) Morphology and function of cuticular micro-scales and corresponding structures in terrestrial isopods (Crustacea, Isopoda, Oniscidea). Zoomorphology 91(3): 263–274. https://doi.org/10.1007/BF00999815

Schmalfuss H (1984) Eco-morphological strategies in terrestrial isopods. Symposium of the Zoological Society of London 53: 49–63.

Schmalfuss H (1998) The terrestrial isopod fauna of the central Near East countries: Composition and biogeography. Israel Journal of Zoology 44: 263–271.

Schmalfuss H (2003) World catalog of terrestrial isopods (Isopoda: Oniscidea). Stuttgarter Beiträge zur Naturkunde, Serie A 654: 1–341.

Schmidt C (1999) Redescription of *Atracheodillo marmorivagus* (Isopoda, Oniscidea, Eubelidae), an arboricolous isopod from Congo and Rwanda. Bonner Zoologische Beitrage 48: 353–365.

Schmidt C (2008) Phylogeny of the terrestrial Isopoda (Oniscidea): a review. Arthropod Systematics & Phylogeny 66(2): 191–226.

Schmidt M, Mellon F (2011) Neuronal processing of chemical information in crustaceans. In: Breithaupt T, Thiel M (Eds) Chemical Communication in Crustaceans. Springer, NY, 123–147. https://doi.org/10.1007/978-0-387-77101-4_7

Schmidt C, Wägele JW (2001) Morphology and evolution of respiratory structures in the pleopod exopodites of terrestrial Isopoda (Crustacea, Isopoda, Oniscidea). Acta Zoologica 82(4): 315–330. https://doi.org/10.1046/j.1463-6395.2001.00092.x

Schornikov EI (1969) A new family of Ostracoda from the supralittoral zone of Kuril Islands. Zoologicheskij Zhurnal 48(4): 494–498. [In Russian]

Schram FR (1986) Crustacea. Oxford University Press, Oxford, 606 pp.

Schubart CD, Cuesta JA, Diesel R, Felder DL (2000) Molecular phylogeny, taxonomy, and evolution of nonmarine lineages within the American grapsoid crabs (Crustacea: Brachyura). Molecular Phylogenetics and Evolution 15(2): 179–190. https://doi.org/10.1006/mpev.1999.0754

Schubart CD, Liu H-C, Cuesta JA (2003) A new genus and species of tree-climbing crab (Crustacea: Brachyura: Sesarmidae) from Taiwan with notes on its ecology and larval morphology. The Raffles Bulletin of Zoology 51(1): 49–59.

Schubart CD, Liu H-C, Ng PKL (2009) Revision of *Selatium* Serène & Soh, 1970 (Crustacea: Brachyura: Sesarmidae), with description of a new genus and two new species. Zootaxa 2154(1): 1–29. https://doi.org/10.11646/zootaxa.2154.1.1

Schwentner M, Combosch DJ, Nelson JP, Giribet G (2017) A Phylogenomic Solution to the Origin of Insects by Resolving Crustacean–Hexapod Relationships. Current Biology 27(12): 1818–1824. https://doi.org/10.1016/j.cub.2017.05.040

Seigel RA (1986) Ecology and conservation of an endangered rattlesnake, *Sistrurus catenatus*, in Missouri, USA. Biological Conservation 35(4): 333–346. https://doi.org/10.1016/0006-3207(86)90093-5

Serejo CS (2004) Cladistic revision of talitroidean amphipods (Crustacea: Gammaridean), with a proposal of a new classification. Zoologica Scripta 33(6): 551–586. https://doi.org/10.1111/j.0300-3256.2004.00163.x

Serejo CS (2009) Talitridae. Zootaxa 2260(1): 892–903. https://doi.org/10.11646/zootaxa.2260.1.51

Serejo CS, Lowry JK (2008) The coastal Talitridae (Amphipoda: Talitroidea) of southern and western Australia, with comments on *Platorchestia platensis* (Krøyer, 1845). Records of the Australian Museum 60(2): 161–206. https://doi.org/10.3853/j.0067-1975.60.2008.1491

Sfenthourakis S, Taiti S (2015) Patterns of taxonomic diversity among terrestrial isopods. ZooKeys 515: 13–25. https://doi.org/10.3897/zookeys.515.9332

Sfenthourakis S, de Araujo PB, Hornung E, Schmalfuss H, Taiti S, Szlávecz K [Eds] (2004) The Biology of Terrestrial Isopods. Crustaceana Monographs 2. Brill, Leiden, 386 pp.

Sfenthourakis S, Orfanou V, Anastasiou Y (2008) A comparative study of isopod assemblages of elevated habitats on five mountains of Peloponnisos peninsula (Greece). In: Zimmer M, Charfi-Cheikhrouha F, Taiti S (Eds) Proceedings of the International Symposium of Terrestrial Isopod Biology–ISTIB–07. Shaker Verlag, Aachen, 13–19.

Sfenthourakis S, Myers AA, Taiti S, Lowry JK (2020) Terrestrial environments. In: Thiel M, Poore G (Eds) Evolution and Biogeography (Vol. 8). Oxford University Press, 359 pp. https://doi.org/10.1093/oso/9780190637842.003.0014

Shachak M (1980) Energy allocation and life history strategy of the desert isopod *H. reaumuri*. Oecologia 45(3): 404–413. https://doi.org/10.1007/BF00540214

Shachak M, Newton P (1985) The relationship between brood care and environmental unpredictability in the desert isopod *Hemilepistus reaumuri*. Journal of Arid Environments 9(3): 199–209. https://doi.org/10.1016/S0140-1963(18)31321-1

Shachak M, Chapman EA, Steinberger Y (1976) Feeding, energy flow and soil turnover in the desert isopod, *Hemilepistus reaumurii*. Oecologia 24(1): 57–69. https://doi.org/10.1007/BF00545487

Shaw J (1996) Australia's rarest crayfish? – A survey of the Labertouche Ck and tributaries in West Gippsland to extend the known range of the Warragul burrowing crayfish (*Engaeus sternalis*). Department of Natural Resources and Environment, Victoria.

Sherman PM (2002) Effects of land crabs on seedling densities and distributions in a mainland neotropical rain forest. Journal of Tropical Ecology 18(1): 67–89. https://doi.org/10.1017/S0266467402002043

Sherman PM (2003) Effects of land crabs on leaf litter distributions and accumulations in a mainland tropical rainforest. Biotropica 35(3): 365–374. https://doi.org/10.1111/j.1744-7429.2003.tb00590.x

Sherman PM (2006) Influence of land crabs *Gecarcinus quadratus* (Gecarcinidae) on distributions of organic carbon and roots in a Costa Rican rain forest. Revista de Biología Tropical 54(1): 149–161. https://doi.org/10.15517/rbt.v54i1.13987

Shih H-T, Do VT (2014) A new species of *Tiwaripotamon* Bott, 1970, from northern Vietnam, with notes on *T. vietnamicum* (Dang and Ho, 2002) and *T. edostilus* Ng and Yeo, 2001 (Crustacea, Brachyura, Potamidae). Zootaxa 3764(1): 026–038. https://doi.org/10.11646/zootaxa.3764.1.2

Shilova-Krassova SA (1952) On the feeding habits of hedgehog (*Erinaceus europaeus* L.) in the southern forests. Zoologicheskij Zhurnal 31: 944–950.

Shinobe S, Uchida S, Mori H, Okochi I, Chiba S (2017) Declining soil Crustacea in a World Heritage Site caused by land nemertean. Scientific Reports 7(1): e12400. https://doi.org/10.1038/s41598-017-12653-4

Simpson R (2011) The invasive biology of the talitrid amphipod *Platorchestia platensis* in North West Europe. The Plymouth Student Scientist 4: 278–292.

Singer C, Bello M, Snyder A (2012) Characterizing prevalence and ecological impact of non-native terrestrial isopods (Isopoda, Oniscidea) in tallgrass prairie. Crustaceana 85(12–13): 1499–1511. https://doi.org/10.1163/15685403-00003126

Skov MW, Vannini M, Shunula JP, Hartnoll RG (2002) Quantifying the density of mangrove crabs: Ocypodidae and Grapsidae. Marine Biology 141(4): 725–732. https://doi.org/10.1007/s00227-002-0867-9

Smigel JT, Gibbs AG (2008) Conglobation in the pill bug, *Armadillidium vulgare*, as a water conservation mechanism. Journal of Insect Science 8(44): 1–9. https://doi.org/10.1673/031.008.4401

Smith TJIII III, Boto KG, Frusher SD, Giddins RL (1991) Keystone species and mangrove forest dynamics: The influence of burrowing by crabs on soil nutrient status and forest productivity. Estuarine, Coastal and Shelf Science 33(5): 419–432. https://doi.org/10.1016/0272-7714(91)90081-L

Sorensen EMB, Burkett RD (1977) A population study of the isopod, *Armadillidium vulgare*, in northeastern Texas. The Southwestern Naturalist 22(3): 375–387.

Sousa FDR, Elmoor-Loureiro LMA, Pannarelli EA (2017) The amazing diversity of the genus *Monospilus* Sars, 1862 (Crustacea: Branchiopoda: Aloninae) in South America. Zootaxa 4242(3): 467–492. https://doi.org/10.11646/zootaxa.4242.3.3

Špaldoňová A, Frouz J (2014) The role of *Armadillidium vulgare* (Isopoda: Oniscidea) in litter decomposition and soil organic matter stabilization. Applied Soil Ecology 83: 186–192. https://doi.org/10.1016/j.apsoil.2014.04.012

Spencer B, Hall TS (1896) On a new genus of terrestrial Isopoda. Proceedings of the Royal Society of Victoria 9, New Series: 12–21.

Spicer JI, Moore PG, Taylor AC (1987) The physiological ecology of land invasion by the Talitridae (Crustacea: Amphipoda). Proceedings of the Royal Society of London, Series B, Biological Sciences 232(1266): 95–124. https://doi.org/10.1098/rspb.1987.0063

Steele DH, Steele VJ (1975) Egg size and duration of embryonic development in Crustacea. Internationale Revue der Gesamten Hydrobiologie und Hydrographie 60(5): 711–715. https://doi.org/10.1002/iroh.19750600609

Stensmyr MC, Erland S, Hallberg E, Wallen R, Greenaway P, Hansson BS (2005) Insect-like olfactory adaptations in the terrestrial giant robber crab. Current Biology 15(2): 116–121. https://doi.org/10.1016/j.cub.2004.12.069

Stensmyr MC, Stieber R, Hansson BS (2008) The Cayman Crab Fly Revisited – Phylogeny and Biology of *Drosophila endobranchia*. PLoS ONE 3(4): e1942. https://doi.org/10.1371/journal.pone.0001942

Storey KB, Storey JM (2012) Aestivation: signaling and hypometabolism. Journal of Experimental Biology 215: 1425–1433. https://doi.org/10.1242/jeb.054403

Suetsugu K, Sueyoshi M (2018) Specialized pollination by fungus gnats in the introduced population of *Aspidistra elatior*. Journal of Plant Research 131(3): 497–503. https://doi.org/10.1007/s10265-017-1007-4

Sunderland KD, Sutton SL (1980) A serological study of arthropod predation on woodlice in a dune grassland ecosystem. Journal of Animal Ecology 49(3): 987–1004. https://doi.org/10.2307/4240

Surbida KL, Wright JC (2001) Embryo tolerance and maternal control of the marsupial environment in *Armadillidium vulgare* Brandt (Isopoda: Oniscidea). Physiological and Biochemical Zoology 74(6): 894–906. https://doi.org/10.1086/324474

Suter PJ, Richardson AMM (1977) The biology of two species of *Engaeus* (Decapoda: Parastacidae) in Tasmania. III. Habitat, food, associated fauna and distribution. Australian Journal of Marine and Freshwater Research 28(1): 95–103. https://doi.org/10.1071/MF9770095

Sutton S (1972) Woodlice. Ginn and Company Limited. London, 144 pp.

Sutton SL (1980) Woodlice (2nd edn.). Pergamon Press, Oxford, 144 pp.

Szlavecz K, Vilisics F, Tóth Z, Hornung E (2018) Terrestrial isopods in urban environments: An overview. ZooKeys 801: 97–126. https://doi.org/10.3897/zookeys.801.29580

Tabacaru I, Danielopol DL (1996) Phyloge´nie des Isopodes terrestres. Comptes Rendus de l'Acade´mie des Sciences, Sciences de la vie 319: 71–80.

Taiti S (2004) Crustacea: Isopoda: Oniscidea (woodlice), 266–267. In: Gunn J (Ed.) Encyclopedia of Caves and Karst Science. Routledge, New York, 896 pp.

Taiti S (2018) A new termitophilous species of Armadillidae from South Africa (Isopoda: Oniscidea). Onychium 14: 9–15.

Taiti S, Ferrara F (1988) Revision of the genus *Exalloniscus* Stebbing, 1911 (Crustacea, Isopoda, Oniscidea). Zoological Journal of the Linnean Society 94(4): 339–377. https://doi.org/10.1111/j.1096-3642.1988.tb01200.x

Takeda N (1980) The aggregation pheromone of some terrestrial isopod crustaceans. Experimentia 36(11): 1296–1297. https://doi.org/10.1007/BF01969598

Takeda S, Kurihara Y (1987) The effects of burrowing of *Helice tridens* (De Haan) on the soil of a salt-marsh habitat. Journal of Experimental Marine Biology and Ecology 113(1): 79–89. https://doi.org/10.1016/0022-0981(87)90084-0

Tanaka K, Udagawa K (1993) Cold adaptation of the terrestrial isopod, *Porcellio scaber*, to subnivean environments. Journal of Comparative Physiology, B, Biochemical, Systemic, and Environmental Physiology 163: 439–444.

Taylor DS (1990) Adaptive specializations of the cyprinodont fish *Rivulus marmoratus*. Florida Scientist 53: 239–248.

Taylor HH, Taylor EW (1992) Gills and lungs: the exchange of gases and ions. In: Harrison FW, Humes AG (Eds) Microscopic Anatomy of Invertebrates, Decapod Crustacea (Vol. 10). Wiley-Liss, NY, 203–293.

Taylor HH, Greenaway P, Morris S (1993) Adaptations to a terrestrial existence by the robber crab *Birgus latro* L. VIII. Osmotic and ionic regulation on fresh water and saline drinking regimens. The Journal of Experimental Biology 179(1): 93–113. https://doi.org/10.1242/jeb.179.1.93

Teuben AT, Roelofsma TAPJ (1990) Dynamic interactions between functional groups of soil arthropods and microorganisms during decomposition of coniferous litter in microcosm experiments. Biology and Fertility of Soils 9(2): 145–151. https://doi.org/10.1007/BF00335798

Thacker RW (1996) Food choices of land hermit crabs (*Coenobita compressus* H. Milne Edwards) depend on past experience. Journal of Experimental Marine Biology and Ecology 199(2): 179–191. https://doi.org/10.1016/0022-0981(95)00192-1

Topp W, Kappes H, Kulfan J, Zach P (2006) Distribution pattern of woodlice (Isopoda) and millipedes (Diplopoda) in four primeval forests of the Western Carpathians (Central Slovakia). Soil Biology & Biochemistry 38(1): 43–50. https://doi.org/10.1016/j.soilbio.2005.04.012

Tsang CTT, Schubart CD, Chu KH, Ng PKL, Tsang LM (2022) Molecular phylogeny of Thoracotremata crabs (Decapoda, Brachyura): Toward adopting monophyletic superfamilies, invasion history into terrestrial habitats and multiple origins of symbio-

sis. Molecular Phylogenetics and Evolution 177: e107596. https://doi.org/10.1016/j.ympev.2022.107596

Tuf IH, Ďurajková B (2022) Antipredatory strategies of terrestrial isopods. ZooKeys 1101: 109–129. hhttps://doi.org/10.3897/zookeys.1101.76266

Turkay M (1973) Bermerkungen zu einigen landkrabben (Crustacea: Decapoda). Bulletin du Muséum National d'Histoire Naturelle 142: 969–980.

Turquin M-J (1983) Un amphipode de la faune du sol en France. In: Lebrun P et al. (Eds) New Trends in Soil Biology, 674–676.

Uesbeck M, Topp W (1995) The effect of leaf litter, microorganisms and Collembola on the food allocation of *Oniscus asellus*. In: Alikhan MA (Ed.) Crustacean Issues 9: Terrestrial Isopod Biology, Balkema, Rotterdam, 121–132.

Ugbomeh AP, Bajor P (2015) Parasites of the brachyuran crab *Cardisoma armatum* from Bakana in Rivers State, Nigeria. Journal of Environmental and Applied Bioresearch 3: 56–60.

Uhlenhaut H (2001) Beobachtungen zum Beutespektrum von Zitterspinnen (Pholcidae). Arachnologische Mitteilungen 22: 37–41. https://doi.org/10.5431/aramit2205

Ulian GB, Mendes EG (1988) Tolerances of a land amphipod, *Talitrus* (*Talitroides*) *pacificus* Hurley, 1955, towards temperature and humidity variations and immersion in water. Revista Brasileira de Biologia 48: 179–187.

Ullrich B, Storch V, Schairer H (1991) Bacteria on the food, in the intestine and on the faeces of the woodlouse *Oniscus asellus* (Crustacea, Isopoda). Pedobiologia 35: 41–51.

van Wensem J (1989) A terrestrial micro–ecosystem for measuring effects of pollutants on isopod-mediated litter decomposition. Hydrobiologia 188/189(1): 507–516. https://doi.org/10.1007/BF00027818

Vannini M, Oluoch A (1993) Notes on *Merguia oligodon* (De Man 1888) the Indo–Pacific semi–terrestrial shrimp (Hippolytidae Natantia). Tropical Zoology 6(2): 281–286. https://doi.org/10.1080/03946975.1993.10539228

Vázquez-López H, Vega-Villasante F, Rodríguez Varela AC, Cruz-Gómez A (2014) Population density of the land crab *Cardisoma crassum* Smith, 1870 (Decapoda: Gecarcinidae) in the estuary El Salado, Puerto Vallarta, Mexico. International Journal of Innovative and Applied Research 2(8): 1–9.

Vilisics F, Sólymos P, Hornung E (2007) A preliminary study on habitat features and associated terrestrial isopod species. In: Tajovsky K, Schlaghamersky J, Pižl V (Eds) Contributions to soil zoology in Central Europe II: Proceedings of the 8th Central European Workshop on Soil Zoology, Ceske Budejovice, 217 pp.

Vogt G (2012) Abbreviation of larval development and extension of brood care as key features of the evolution of freshwater Decapoda. Biological Reviews of the Cambridge Philosophical Society 88(1): 81–116. https://doi.org/10.1111/j.1469-185X.2012.00241.x

Vogt G (2016) Structural specialities, curiosities and record-breaking features of crustacean reproduction. Journal of Morphology 277(11): 1399–1422. https://doi.org/10.1002/jmor.20582

Waltham N (2016) Unravelling life history of the Inland Freshwater Crab Austrothelphusa transversa in seasonal tropical river catchments. Australian Zoologist 38(2): 217–222. https://doi.org/10.7882/AZ.2016.034

Wan C, Gorb SN (2021) Body-catapult mechanism of the sandhopper jump and its biomimetic implications. Acta Biomaterialia 124: 282–290. https://doi.org/10.1016/j.actbio.2021.01.033

Wang W (2011) Bacterial diseases of crabs: A review. Journal of Invertebrate Pathology 106(1): 18–26. https://doi.org/10.1016/j.jip.2010.09.018

Warburg MR (1964) The response of isopods towards temperature, humidity and light. Animal Behaviour 12(1): 175–186. https://doi.org/10.1016/0003-3472(64)90119-8

Warburg MR (1965a) The evaporative water loss of three isopods from semi–arid habitats in South Australia. Crustaceana 9(3): 302–308. https://doi.org/10.1163/156854065X00073

Warburg MR (1965b) Water relation and internal body temperature of isopods from mesic and xeric habitats. Physiological Zoology 38(1): 99–109. https://doi.org/10.1086/physzool.38.1.30152347

Warburg MR (1968) Behavioral Adaptations of Terrestrial Isopods Am. Zoologist 8: 545–559. https://doi.org/10.1093/icb/8.3.545

Warburg MR (1987) Isopods and their terrestrial environment. Advances in Ecological Research 17: 187–242. https://doi.org/10.1016/S0065-2504(08)60246-9

Warburg MR (1993) Evolutionary Biology of Land Isopods. Springer, Berlin. https://doi.org/10.1007/978-3-662-21889-1

Warburg MR, Rosenberg M (1996) Brood pouch structures in terrestrial isopods. Invertebrate Reproduction & Development 23(3): 213–222. https://doi.org/10.1080/07924259.1996.9672515

Warburg M, Cohen N, Weinstein D, Rosenberg M (1993) Life history of a semelparous oniscid isopod, *Schizidium tiberianum* Verhoeff, inhabiting the Mediterranean region of northern Israel. Israel Journal of Zoology 39: 73–85.

Ward D (2009) The Importance of Predation and Parasitism. The Biology of Deserts. Biology of Habitats. Oxford University Press, 124–144. https://doi.org/10.1093/acprof:oso/9780199211470.003.0006

Watson-Zink VM (2021) Making the grade: Physiological adaptations to terrestrial environments in decapod crabs. Arthropod Structure & Development 64: e101089. https://doi.org/10.1016/j.asd.2021.101089

Wehrtmann IS, Magalhães C, Bello-González OC (2016) First confirmed report of a primary freshwater crab (Brachyura: Pseudothelphusidae) associated with bromeliads in the Neotropics. Journal of Crustacean Biology 36(3): 303–309. https://doi.org/10.1163/1937240X-00002429

Weihmann T (2020) Survey of biomechanical aspects of arthropod terrestrialisation. Substrate bound legged locomotion. Arthropod Structure & Development 59: e100983. https://doi.org/10.1016/j.asd.2020.100983

Weinstein RB (1998) Effects of temperature and water loss on terrestrial locomotor performance in land crabs: Integrating laboratory and field studies. American Zoologist 38(3): 518–527. https://doi.org/10.1093/icb/38.3.518

Weinstein RB, Full RJ (1994) Thermal dependence of locomotor energetics and endurance capacity in the ghost crab, *Ocypode quadrata*. Physiological Zoology 67(4): 855–872. https://doi.org/10.1086/physzool.67.4.30163868

Weinstein RB, Full RJ, Ahn A (1994) Moderate dehydration decreases locomotor performance of the ghost crab, *Ocypode quadrata*. Physiological Zoology 67(4): 873–891. https://doi.org/10.1086/physzool.67.4.30163869

Welch SM, Eversole AG (2006) An ecological classification of burrowing crayfish based on habitat affinities. Freshwater Crayfish 15: 155–161.

Welch SM, Waldron JL, Eversole AG, Simoes JC (2008) Seasonal variation and ecological effects of Camp Shelbyburrowing crayfish (Fallicambarus gor-

doni) burrows. American Midland Naturalist 59(7): 378–384. https://doi.org/10.1674/0003-0031(2008)159[378:SVAEEO]2.0.CO;2

White JJ (1968) Bioenergetics of the woodlouse *Tracheoniscus rathkei* Brandt in relation to litter decomposition in a deciduous forest. Ecology 49(4): 694–704. https://doi.org/10.2307/1935533

Wiens H (1962) Atoll Environment and Ecology. Yale University Press, New Haven.

Wildish DJ (1979) Reproductive consequences of the terrestrial habit in *Orchestia* (Crustacea, Amphipoda). International Journal of Invertebrate Reproduction and Development 1(1): 9–20. https://doi.org/10.1080/01651269.1979.10553295

Williams T (2008) Natural invertebrate hosts of iridoviruses (Iridoviridae). Neotropical Entomology 37(6): 615–632. https://doi.org/10.1590/S1519-566X2008000600001

Williams M, Leng ML, Stephenson MH, Andrews JE, Wilkinson IP, Siveter DJ, Horne DJ, Vannier JMC (2006) Evidence that Early Carboniferous ostracods colonized coastal flood plain brackish water environments. Palaeogeography, Palaeoclimatology, Palaeoecology 230(3–4): 299–318. https://doi.org/10.1016/j.palaeo.2005.07.021

Williamson DI (1951) On the mating and breeding of some semi-terrestrial amphipoda. Kings College, Dove Marine Laboratory Report, series 3 12: 49–62.

Wilson GDF, Keable SJ (2002) New Phreatoicidea (Crustacea: Isopoda) from Grampians National Park, with revisions of *Synamphisopus* and *Phreatoicopsis*. Memoirs of the Museum of Victoria 59(2): 457–529. https://doi.org/10.24199/j.mmv.2002.59.10

Windsor A, Crowe M, Bishop J (2005) Determination of temperature preference and the role of the enlarged cheliped in thermoregulation in male sand fiddler crabs, *Uca pugilator*. Journal of Thermal Biology 30(1): 37–41. https://doi.org/10.1016/j.jtherbio.2004.06.006

Wolcott TG (1988) Ecology. In: Burggren WW, McMahon BR (Eds) Biology of Land Crabs. Cambridge University Press, NY, 55–96. https://doi.org/10.1017/CBO9780511753428.004

Wolcott DL (1991) Nitrogen excretion is enhanced during urine recycling in two species of terrestrial crab. Journal of Experimental Zoology 259: 181–187. https://doi.org/10.1002/jez.1402590206

Wolcott DL, Wolcott TG (1984) Food quality and cannibalism in the red land crab, *Gecarcinus lateralis*. Physiological Zoology 57: 318–324. https://doi.org/10.1086/physzool.57.3.30163720

Wolcott DL, Wolcott TG (1987) Nitrogen limitation in the herbivorous land crab *Cardisoma guanhumi*. Physiological Zoology 60: 262–268. https://doi.org/10.1086/physzool.60.2.30158650

Wolcott TG, Wolcott DL (1990) Wet behind the gills. Natural History 10/90: 46–55. https://doi.org/10.4037/ccn1990.10.3.78

Wolfe JM, Ballou L, Luque L, Watson-Zink VM, Ahyong ST, Barido-Sottani J, Chan T-Y, Chu KH, Crandall KA, Daniels SR, Felder DL, Mancke H, Martin JW, Ng PKL, Ortega-Hernández J, Theil EP, Pentcheff ND, Robles R, Thoma BP, Tsang LM, Wetzer R, Windsor AM, Bracken-Grissom HD (2022) Convergent adaptation of true crabs (Decapoda: Brachyura) to a gradient of terrestrial environments. BioRxiv preprints 2022. https://doi.org/10.1101/2022.12.09.519815

Wongkamhaeng K, Dumrongrojwattana P, Shin M-H (2018) Discovery of a new genus and species of dogielinotid amphipod (Crustacea: Amphipoda: Dogielinotidae) from the *Nipa* palm in Thailand, with an updated key to the genera. PLoS ONE 13(10): e0204299. https://doi.org/10.1371/journal.pone.0204299

Wood CT, Nihei SS, Araujo PB (2018) Woodlice and their parasitoid flies: Revision of Isopoda (Crustacea, Oniscidea) – Rhinophoridae (Insecta, Diptera) interaction and first record of a parasitized Neotropical woodlouse species. ZooKeys 801: 401–414. https://doi.org/10.3897/zookeys.801.26052

Wright JC, Ting K (2006) Respiratory physiology of the Oniscidea: Aerobic capacity and the significance of pleopodal lungs. Comparative Biochemistry and Physiology 145(2): 235–244. https://doi.org/10.1016/j.cbpa.2006.06.020

Zimmer M (1999) The fate and effects of ingested hydrolyzable tannins in *Porcellio scaber*. Journal of Chemical Ecology 25(3): 611–628. https://doi.org/10.1023/A:1020962105931

Zimmer M (2002a) Nutrition in terrestrial isopods (Isopoda: Oniscidea): an evolutionary–ecological approach. Biological Reviews of the Cambridge Philosophical Society 77(4): 455–493. https://doi.org/10.1017/S1464793102005912

Zimmer M (2002b) Is decomposition of woodland leaf litter influenced by its species richness? Soil Biology & Biochemistry 34(2): 277–284. https://doi.org/10.1016/S0038-0717(01)00173-0

Zimmer M, Brune A (2005) Physiological properties of the gut lumen of terrestrial isopods (Isopoda: Oniscidea): adaptive to digesting lignocellulose? Journal of Comparative Physiology. B, Biochemical, Systemic, and Environmental Physiology 175(4): 275–283. https://doi.org/10.1007/s00360-005-0482-4

Zimmer M, Topp W (1997) Does leaf litter quality influence population parameters of the common woodlouse, *Porcellio scaber* (Crustacea: Isopoda)? Biology and Fertility of Soils 24(4): 435–441. https://doi.org/10.1007/s003740050269

Zimmer M, Topp W (1998a) Microorganisms and cellulose digestion in the gut of *Porcellio scaber* (Isopoda: Oniscidea). Journal of Chemical Ecology 24(8): 1397–1408. https://doi.org/10.1023/A:1021235001949

Zimmer M, Topp W (1998b) Nutritional biology of terrestrial isopods (Isopoda: Oniscidea): Copper revisited. Israel Journal of Zoology 44: 453–462.

Zimmer M, Topp W (2000) Species-specific utilization of food sources by sympatric woodlice (Isopoda: Oniscidea). Journal of Animal Ecology 69(6): 1071–1082. https://doi.org/10.1046/j.1365-2656.2000.00463.x

Zimmer M, Pennings SC, Buck TL, Carefoot TH (2002) Species-specific patterns of litter processing by terrestrial isopods (Isopoda: Oniscidea) in high intertidal salt marshes and coastal forests. Functional Ecology 16(5): 596–607. https://doi.org/10.1046/j.1365-2435.2002.00669.x

Zimmer M, Kautz G, Topp W (2003) Leaf litter-colonizing microbiota: supplementary food source or indicator of food quality for *Porcellio scaber* (Isopoda: Oniscidea)? European Journal of Soil Biology 39(4): 209–216. https://doi.org/10.1016/j.ejsobi.2003.07.001